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# REPORT

of

Committee on Thesis

The undersigned, acting as a Committee of the Graduate School, have read the accompanying thesis submitted by Lloyd H. Rutledge. for the degree of Master of Arts. They approve it as a thesis meeting the requirements of the Graduate School of the University of Minnesota, and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts.

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Chairman

R E Scammon

H. E. Robertson

May 31, 1916

REPORT

of

Committee on Examination

This is to certify that we the undersigned, as a Committee of the Graduate School, have given Lloyd H. Rutledge final oral examination for the degree of Master of Arts. We recommend that the degree be conferred upon the candidate.

Minneapolis, Minnesota.

May 31, 1916

C. M. Jackson
Chairman

R. E. Scammon

H. E. Robertson

# The Morphology of the Digestive and Respiratory Tracts in a 20 Millimeter Pig Embryo.

A Thesis

Submitted to the Faculty

of the

Graduate School

of

The University of Minnesota

by

Lloyd H. Rutledge

In partial fulfillment of the requirements for

the degree

of

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# INTRODUCTION

The 20 mm. stage of the pig embryo marks many important transitions in the developmental history of this animal. Especially is this true of the digestive tract and its derivatives, including the respiratory tract. Various portions of these systems have already been described in their separate parts, but an accurate description of the morphology of these tracts as a whole seems highly desirable. The purpose of the present study is so far as possible to bridge the existing gaps in our knowledge of this stage as well as to confirm the scattering observations of previous investigators.

This work was suggested by Prof. F. P. Johnson, of the University of Missouri, under whose directions the early observations were made. The work has been continued and completed in the Anatomical Laboratory of the University of Minnesota under the direction of Prof. C. M. Jackson. I take this opportunity to express my indebtedness to both Dr. Johnson and Dr. Jackson.

## MATERIAL AND METHODS.

A 20 mm. pig embryo from the Harvard Embryological Collection (H.E.C.1702), cut in transverse serial sections of 16 microns, was used as the basis for study. A series of wax reconstructions (Born's method) was made of the entire tracts*, excepting the liver and portions of the intestine. This was supplemented by a graphic reconstruction of the entire tracts (fig.1). A part of the umbilical portion of the intestinal loop had been removed before the pig was sectioned. A drawing of this region was added (in fig.1) from dissections of other embryos of the same length to supply the missing portion. For comparisons, in addition to dissections, several sectioned embryos of nearly the same length from the Missouri and the Minnesota Embryological Collections were studied. In all cases a careful microscopic study of the serial sections was made to determine accurately the structure and relations (including variations) and to aid in interpreting the models. In comparing with other stages and species only incidental references to literature will be made, as my observations have been confined to pig embryos in the neighborhood of 20 mm. in length. All embryos were measured in crown-rump length.

*The models of the nose, mouth and pharynx (figs. 2, 3, 4) were reconstructed by Prof. F. P. Johnson, to whom I am greatly indebted for permission to use them in the present study.

## LITERATURE AND OBSERVATIONS

In the literature on the pig embryo there has been some confusion in the use of terms of position and direction. The words anterior and posterior are often used in the adult sense, usually meaning cephalic and caudal, and superior and inferior (especially in the head region) meaning dorsal and ventral. In my own observations the notochord with an imaginary prolongation to the snout is taken as the body axis. From this axis the central nervous system is dorsal (dorsad), the alimentary canal ventral (ventrad). Cephalic (cephalad) is used to refer to the head end (snout) of the embryo. Caudal (caudad) means toward the tail. Anterior and posterior where used have the same meaning as cephalic and caudal respectively. Superior and inferior mean dorsal and ventral, except in the case of the lungs (where Flint's terminology is followed).

### I. MOUTH

#### a. Literature

In reviewing the literature only the more important observations and points of controversy will be mentioned. Furthermore, only those near the 20 mm. stage are primarily concerned, earlier and later developmental stages receiving merely incidental mention.

Keibel ('97) records the presence of the dental ridges in a pig embryo of 19.5 mm.

Fox ('08) shows the vestibular folds of the mouth in a 20 mm. pig.

See note (a), page 44a.

Regarding the time, order of appearance and form of the anlages of the salivary glands, the evidence is somewhat conflicting.

Chievitz ('85), one of the early investigators in this field, states that the submaxillary gland in the pig arises from the lingual sulcus caudad to the lingual nerve. The sublingual gland according to his account arises (21.5 mm. pig) from a common crest with the submaxillary gland; hence it would seem that the sublingual is a derivative of the submaxillary anlage. The order of their appearance, as found by Chievitz, in pigs near the 20 mm. stage, is: submaxillary, sublingual and parotid.

Göppert ('08), in his work on the development of the mouth describes the anlages of the salivary glands in the pig in early stages. The submaxillary gland anlage is a ridge-like structure springing as a solid epithelial sprout ("Spross") from the thickened epithelium at the side of the root of the tongue, a short distance behind the frenulum linguae; thus it does not arise at the place where the duct later opens. On the outside of the submaxillary anlage is the anlage of the sublingual gland, and together they press in the mesenchyma against the lingual nerve. In a 22 mm. pig, this author described the parotid as arising from a solid sprout at the angle of the lips.

Schulte ('12) in describing the salivary glands in different species reports for the pig as follows: In one 15 mm. embryo the submaxillary anlage alone is present; in a second embryo of the same length the submaxillary gland is more advanced and the anlage of the sublingual major is present, the two anlages being separated from each other. In a 19 mm. embryo both gland anlages are attached to the lingual sulcus by a single narrow plate of epithelium. This condition Schulte explains as being secondary and caused by the closure of the lingual sulcus. "When the sulcus is obliterated, a common flange is formed, along which both submaxillary and sublingualis major advance independently. This type is found in the pig; it is likely that it also occurs in man, but as yet the evidence is incomplete."

Moral ('12a) finds the submaxillary anlage in the pigs near the 20 mm. stage arising from the epithelium of the mouth cavity, beginning like a ledge ("leistenförmig"). The anlage of this gland first appears at a point where the epithelium from the side of the mouth joins that of the tongue. He figures the sublingual anlage as joined to the submaxillary, the two being connected to the lingual sulcus by a common plate (fig.11,p.308; younger than Keibel's 19.5 mm. pig). In a separate paper ('12b) on the parotid in the pig he describes this gland as developing from a solid epithelial anlage. He states that it is the last of the three salivary glands to appear, but finds one case where it precedes the sublingual. He seems to agree with Göppert that the parotid arises as a solid sprout at the junction of the roof and floor of the mouth close behind the commissure of the lips.

## b. Observations

The mouth forms a gradual curve or arch with the pharynx and is in open communication with the nasal cavities. The thickened mesenchymal anlages of the upper jaws are pressing in upon its dorsal surface tending to separate the vestibulum oris from the cavum oris proprium.

On the lateral sides are the two prominent vestibular folds (figs. 2 and 4 V.F.) which extend caudad along either side of the pharynx and become continuous with the tonsillary folds of the second pharyngeal pouch (figs.2 and 4 T.F.). The vestibular folds are similar on the two sides, each consisting of a dorsal half (roof) and a ventral half (floor), enclosing the mouth cavity.

Each vestibular fold presents a prominent rounded knob (figs. 2 and 4, k), which projects dorsad sloping laterad and slightly cephalad to the commissure (fig.2, C.L.) of the lips. The significance of these knob-like structures is uncertain. On the dorsal surface of the roof of the vestibular folds is the U-shaped superior dental ridge (figs.2 and 4, S.D.R.). The ventral surface of floor of the vestibular fold on each side is roughened and presents two small rounded prominences (fig.2,p'p"). These rounded prominences are separated from each other by a shallow groove and apparently are only thickened places in the epithelium showing no evidence of constriction or gland formation. Lateral to these is the stalk-like anlage of the parotid gland (figs. 2 and 4,D.P.G.) having its origin immediately caudal to the angle of the mouth. The floor of the vestibular fold is limited medially by the lingual sulcus. The inferior dental ridge (fig.3,I.D.R.) occupies a position in the floor of the mouth similar to that of the superior dental ridge (figs. 2 and 4,S.D.R.) in the roof of the mouth. Both somewhat resemble in form the letter "U", the inferior one being slightly narrower but placed opposite the superior dental ridge. Between the lingual sulci on either side, the floor of the mouth is sharply vaulted by the developing tongue (fig.3, A.T.). The epithelium of the mouth is folded beneath the tip of the tongue (fig.3,M.C.U.T.). These fade away gradually as they pass along the side wall of the mouth toward the pharynx.

With regard to the cavity of the mouth little need be said. It opens externally in the form of a semicircle (figs. 1 and 2,O.M.) bounded by the two lips and their lateral commissures (fig.2,C.L.). The upper lip slightly overhangs the lower (fig.2,U.L. and L.L.), the latter being rolled down and slightly everted. The mouth cavity is compressed dorsoventrally forming a narrow transverse slit (fig.3, M.C.). The hypophysis has no connection with the buccal cavity at this time (fig.1,Hy.).

The salivary glands will be described briefly. The parotid as mentioned above arises from a solid epithelial cord just caudal to the angle of the mouth. This cord extends caudad, exhibiting a slight ventral concavity. The right anlage, near its middle, divides into three subdivisions (fig.4,x') which unite again to form a single cord. On the left side the anlage shows a slight swelling (fig.4,x ) in the corresponding place. The significance of these subdivisions and swelling is doubtful, no mention of similar structures having been found in the literature. The anlage of the gland terminates just cephalad and slightly lateral to the main part of the submaxillary gland (figs. 1 and 2, S.M.G.).

The submaxillary gland arises by a solid cord from the lingual sulcus (fig.3, D.S.M.G.). The gland is connected to the oral epithelium by a common plate with the sublingual gland (fig. 3, D.S.L.G.). Chievitz ('85) states that the glands arise from a common crest, while Schulte ('12) thinks this is only a secondary condition and finds that it occurs in a 19 mm. pig. Moral('12), figures a similar condition (his fig.11, p.308).

The cord-like anlage of the submaxillary gland takes a caudal direction arching slightly dorsad and terminating in a lobulated body just ventral to the lowest part of the first entodermal pouch (figs. 1 and 2, Ent. .I).

As mentioned above, the sublingual gland (figs. 2 and 3,D.S.L.G) arises from a common plate with the submaxillary gland, but on its lateral side. It follows the cord of the submaxillary closely, both pressing against the lateral aspect of the lingual nerve. The anlage of the sublingual gland is a short, solid epithelial stalk or cord, about half the length of the submaxillary anlage in this specimen. It presents no branching or lobulation and is by far the smallest of the three glands at this time. This would indicate perhaps that both the other glands precede it in their development in this embryo. Lateral to the sublingual gland there is a very small crest which suggests the "sublingualis minor" of Schulte ('12) (fig.3,Z), but no final conclusion could be determined from this stage alone.

## II. NOSE

In reviewing the literature on the nose only the more recent articles will be considered; from these the reader may obtain a résumé of earlier treatises.

### a. Literature

Peter ('06) describes the nasal apparatus in different species. In regard to the nasal glands he states there is a lateral nasal gland which was discovered by Steno and later described by Jakobson, Kangro and Schwink. According to Peter's account, it arises from the anterior part of the middle meatus and extends into the inferior concha, forming acini which penetrate into the mucosa of the maxillary air sinus. To quote Peter: "Die Drüse verhält sich ziemlich gleichmässig bei den untersuchten Arten (Manis, Schaf, Schwein, Reh, Hirsch, Elen, Pferd, Maus, Meerschweinchen, Kaninchen, Hund, Katze, Igel, Fledermaus)." But he finds this gland is absent in human embryos.

See note (b) page 44a.

Peter ('12) in his work on the development of the turbinals, figures a 13 mm. pig (his fig.10a,p.460) showing four ethmoturbinals. He states that other authors have given three, but says that the number may range from three to four. He observed one case where five were present. The ethmoturbinals arise by outgrowths from the dorso-caudal part of the olfactory region. As to further differentiation he states: "Das Prinzip der weiteren Differenzierung ist dann stets das gleiche: es werden durch Furchen nach innen vorspringende Wülste, die Ethmoturbinalien, abgeschnürt; neue sekundäre Furchen können diese primären Muscheln teilen order zwischen ihnen neue einschieben, die aber nur selten von innen her sichtbar werden. Die Zahl der primären Ethmoturbinalien ist bei den einzelnen Formen der Säuger verschieden; ein gemeinsamer Grundtypus, von dem sich alle Erscheinungsformen ableiten liessen, lässt sich nicht aufstellen."

Frets ('12 and '14) gives very extensive accounts of the comparative anatomy and development of the nose of primates. He describes the formation of the gums and cartilages, and their relations to the nasal cavities. There is one point to be brought out in this connection with regard to the ductus glandularum recessus maxillaris. According to Frets ('12) it begins in the lower part of the nasal cavity somewhat ventral to the nasoturbinal, bending ventrally it reaches the corner between the lateral wall and the maxilloturbinal and loses itself in the beginning of the maxillary recess in a small gland tube (Drüsenröhrchen).

Tüffers ('13) reviews the literature on the nasolacrimal duct and its connections with the nasal meatuses. He finds that the duct differs in different species as to place and number of openings into the nose. The rabbit, cat, calf, sheep and horse show the duct with an anterior (more cephalic) opening and not tending to enclosure under the nasal concha. In the duckbill, opossum, mouse and bats, the nasolacrimal duct tends to become enclosed under the nasal epithelium below (ventral to) the inferior concha. Furthermore, there are animals in which the duct has two openings, as the dog (in several cases) and the pig. In man, only the posterior (more caudal) opening is found and the cephalic part of the duct is absent or occasionally rudimentary.

### b. Observations

In the 20 mm. pig the nasal cavities are two irregularly shaped elongated bodies. They extend from the nares caudad (figs. 1 and 2, N.A.) to the posterior blind sac (figs. 1 to 4, P.B.S.). Ventro-caudad each nasal cavity has, through the primitive choana, a narrow, elongated communication with the mouth cavity (figs. 1 to 4, Ch.). In profile the general curve of the nasal cavities is parallel with the curvature of the mouth (figs. 1 and 2).

Each nasal cavity may be described as having two surfaces, a medial and a lateral, continuous with each other at their margins, excepting at the primitive choanae. In the region of the nares, the nasal cavities are widely separated by the premaxillae and septal cartilage, but caudally in the region of the posterior blind sacs the two cavities are in close apposition (fig. 4, P.B.S.).

The medial surfaces of the nasal cavities (fig.3) are flat and describe a gentle sigmoid curve longitudinally. The small blind pouch of Jacobson's organ (fig.3, J.O.) is situated immediately cephalodorsad to the junction between nose and mouth. It comes off in a medial direction but turns caudad to lie against the septal side of the medial surface of the nasal mucosa. It is constricted at its origin where it communicates with the nasal cavity and terminates in a pointed extremity.

The lateral surface of each nasal cavity is thrown into a number of folds by the developing conchae. Caudad in the region of the blind sac, can be seen three depressions of the ethmoturbinals (figs. 2 and 4, Et. I, II, III). The third is indistinct but the first two are well marked and according to Peter ('06) persist to form ethmoid cells. The first of these shows externally a distinct secondary depression producing two smaller outpouchings. The second and third ethmoturbinal outpouchings show no distinct subdivisions.

Cephalad (rostrad) to the first ethmoturbinal may be seen the depression of the nasoturbinal (fig.2, N.T.). In the caudal region of the nasoturbinal depression there is a complicated outgrowth which would seem to correspond internally to the concha obtecta (fig.2, C.A.) described by Peter ('06) in the rabbit and human. Ventrad to the cephalic portion of the nasoturbinal is the sharp outfolded margin of the middle meatus (fig.2, M.M.). The caudal end of this meatus is thrown into a complex outpouching (fig.2, R.F.). This complex is associated with the concha obtecta just mentioned. Just what develops from this part of the middle meatus is uncertain from this stage alone; but it would seem that the ventrocephalic part corresponds to the recessus inferior of Peter (fig.2, R.I.) representing the anlage of the maxillary sinus while the dorsocaudal part of the pouch corresponds to the recessus frontalis of Peter ('06). According to Keibel ('12) the recessus frontalis of the human gives rise to sinus frontalis and the upper and anterior ethmoidal cells (frontal cells).

A small tube-like gland arising from the lateral surface of the nasoturbinal extends caudad along the crest-like margin of the meatus terminating in a slight swelling opposite the recessus inferior of the middle meatus. This is evidently the lateral nasal gland (fig.2, L.N.G.) described by Peter, and seems to correspond to the <u>ductus glandularum recessus maxillaris</u> which Frets finds in apes.

The nasolacrimal duct (fig.2,N.L.D.) is a small tube-like structure lightly fused with the dorsal margin of the inferior meatus, with cephalic and caudal extremities ending blindly. According to Tüffers' account of this structure, there are two openings in the adult pig, the anterior of which is phylogenetically the older. In this specimen the duct is attached only loosely to the epithelium of the inferior meatus and if an earlier communication has existed here or with the middle meatus (as its position would seem to indicate) it is lost at this time. A very small lumen exists in this duct but the duct ends blindly having no communication with the nasal cavity or the conjunctival sac.

Ventrocaudad to the nasoturbinal the processus navicularis of the maxilloturbinal (fig.2,M.T.) produces a deep depression. Ventrad to this is the inferior nasal meatus (fig.2,I.M.), thrown out in the form of a flat, elongated spur.

## III. PHARYNX

### a. Literature

The literature on the pharynx will be taken up chronologically in order of the pouches, grouping the first and second pouches together because of their common relations.

1. First and second pharyngeal pouches. Kastshenko ('87) describes the first and second pharyngeal pouches as united in the pig between the 15 and 20 mm. stages and thinks that the first pharyngeal pouch in no way gives origin to the middle ear, but rather that the middle ear is formed by a narrowing of the side wall of the pharynx. Between the second and third arches he mentions an outpouching from the pharynx, the fossa of Rosenmüller, which he

describes as being present in the pig embryo between the 15 and 52 mm. stages.

Fox ('08) described the first pouch (in 18 to 24 mm. pigs) as a broad, flattened projecting fold, turning up at the periphery, so that the dorsal apex is higher than the pharynx. At the dorsal apex the tubo-tympanal and tensor-tympanal borders meet, thus forming an arch. The sub-meckelian fold lies on the side of this pouch. In regard to the first pouch in a 20 mm. pig, Fox says: "An important, but at this time inconspicuous, feature is a shallow indentation on the posterior tympanal rim between the first and second pouch (see figs. 26-27, x ). The latter pouch is now so small that the exact line of demarcation is not easily recognizable. A slight ridge, however, which extends from the indentation to the sub-meckelian fold, enables one to fix upon this point as being between the two structures." This statement is not quite clear in view of his later description of the second pouch (20 mm. pig). He states that "Posteriorly the second pouch thus forms a low ridge situated on the outer side of the ventrolateral fold (=conjoined alveolo-lingual and piriform sinuses)." The filiform process which earlier connected the second pouch with the ectoderm he finds to be still recognizable in a pig of this age. In a 24 mm. pig Fox describes the two pouches as being entirely separate. The first pouch is constricted at the base and the posterior (caudal) part ends in a wide cup-shaped fold. The second pouch now forms the tonsillary fold and is completely removed from the first, forming a prominent fold on the side of the pharynx (Fox's fig. 29).

2. <u>The third pouch and the thymus</u>. Kastschenko ('87) in an 18 mm. pig shows the thymus as consisting of a thymus superficialis, vesicula thymica, caput and cauda. Thymus superficialis he con-

siders as derived from the ectoderm and at this stage it is lateral, hooking above the hypoglossal nerve. Also, he thinks a part of the head comes from the ectoderm while the remainder of the gland develops from the third entodermal pouch.

Bell ('05) describes the thymus in the 20 mm. pig as extending down into the thorax and uniting with its fellow of the opposite side. He finds no connection with the pharynx or ectoderm in the head region. He notes the relation of the hypoglossal nerve as described by Kastschenko. It is Bell's opinion that no part of the thymus arises from the ectoderm.

Fox ('08) finds the thymus on the left side separated from the pharynx in the 20 mm. pig, but on the right side it is still in connection. The ventral extremity is slightly lobed. The dorsal extremity he describes as consisting of a fundus precervicalis, a carotid gland and a dorsal plate which is wedged in between the two former structures. In a 24 mm. pig this complex is so fused that Fox says it is almost impossible to distinguish them. He finds no lumen in the thymus at the 20 mm. stage. The bulk of the thymus he thinks is derived from the ventral diverticulum of the third pouch, the carotid gland developing from the dorsal part of the same pouch.

Zotterman ('11) finds the thymus still united with the pharynx in a 21 mm. pig. The ductus precervicalis is small and has no lumen, a small portion of the duct being atrophied near the ectoderm. The parathyroid III described by her corresponds to the carotid gland described by Fox ('08).

Badertscher ('15) has worked out very carefully the morphogenesis of the thymus and says that in a 21.5 mm. pig it consists of the following divisions: "(1) The 'superficial thymus' which represents the vesicula certicalis lateralis and is of a purely ectodermal origin; (2) the 'thymus head' which represents the structure formed by the fusion of the vesicula cervicalis medialis and the anterior portion of the entodermal anlage of the thymus; (3) the 'connecting gland' which loops over the hypoglossal nerve and connects the superficial thymus with the thymus head and is of purely ectodermal origin; (4) the 'mid-cervical segment' which is an enlargement of the thymus between the intermediary and cervico-thoracic cords; (5) the 'intermediary cord' which connects the thymus head with the mid-cervical segment; (6) the 'thoracic segment' which lies in the anterior (cephalic) portion of the thorax and is spread over a portion of the pericardium; and (7) the 'cervico-thoracic cord' which unites the mid-cervical segment to the thoracic segment." Badertscher finds that the thymus has no connection with the pharynx in the 21.5 mm. pig, and that the thoracic segments of the two sides are not fused.

From a brief summary of the literature on the thymus it would appear that the thymus is fused with parathyroid III (carotid gland of Fox), which lies on the dorsomedial part of the head of the thymus. The vesicula cervicalis lateralis of Badertscher is connected with the thymic head dorsal to the hypoglossal nerve. The connections with the pharynx and ectoderm are lost in the pig near 20 mm. stage. The cervical thymus and thoracic thymus are joined by a solid epithelial cord, which according to Badertscher shows a mid-cervical enlargement. The thoracic segments are not fused in a 21.5 mm. pig examined by Badertscher, but Bell reports them fused in a 20 mm. pig. Kastschenko, Zotterman, and Badertscher describe the thymus as of ectodermal and entodermal origin; Bell and Fox, on the other hand, think the gland is only of entodermal origin.

3. The fourth pouch and the thyroid gland.-- Born ('83) in the pharynx of 20 mm. pig finds that the thyroid anlage is close upon the third arch of the aorta, with the thymus anlage extending along its sides and ending on the pericardium. The anterior (median) anlage comes to lie close to the two lateral, the three being in apposition in the 19 mm. pig, and fused in pigs over 20 mm.

Kastschenko ('87) reports that in the pig the lateral anlages of the thyroid complex are formed on the outer wall of the pharynx at the opening of the oesophagus and extend parallel with the oesoph-agus. Near the 18 mm. stage the two lateral anlages join the median and break loose from the fourth pouch of the pharynx.

Fox ('08) says that the median anlage of the thyroid gland has moved backward and is situated immediately in front of the trachea (20 mm. pig), the lateral wings have grown over the outer side of the lateral thyroids and thus the latter elements are partly imbedded in the median anlage. In a 20 mm. pig he finds the lateral anlages connected with the fourth pouch, but this connection is lost in the 24 mm. pig.

Moody ('10) says the thyroid gland in the 20 mm. pig consists of a single mass, but that the lateral elements have not yet been invaded by blood vessels and can easily be distinguished from the median anlage.

See note (c) page 44a.

b. Observations

1. General morphology.-- The pharynx forms a distinct arch with the mouth (figs.1 and 2), the most prominent part of the arch corresponding to the region of the first pouch (fig.2,Ent.I) as noted by Fox in pigs of similar age. It is compressed dorso-ventrally and the first pouch is seen projecting out in the form of a large wing (fig.4,Ent.P.I). The lateral margin of the pharynx is

rounded, continuous cephalad with the vestibular fold of the mouth (figs. 2 and 4,V.F.) and extending caudad as the tonsillary fold (fig.4,T.F.), and sinus piriformis (figs.2 and 4,S.Pi). Caudally the lateral margin of the pharynx terminates as the lateral margin of the oesophagus (figs.1,2,3,Oe.). Cephalad of the first pouch and lying ventrally and medial to the vestibular fold may be seen the alveolo-lingual fold (fig.2, A.L.F.). This continues caudad, becoming indistinct in the region of the tonsillary fold (figs.2 and 4,T.F.).

Dorsally (fig.4) the pharynx is seen to be wider at the first pouch, gradually narrowing in a caudal direction where it presents a blind projecting pouch, the pharyngeal bursa (figs.1,2,3,4,Ph.B.). Dorsally is the notochord, separated from the pharyngeal wall by mesenchyma and the developing cartilages. The notochord terminates just dorsal to the pharynx in the region of the first pouch. A glance at figure 1 will show the relations between pharynx (Ph.), notochord (Nc.), hypophysis (Hy.) and brain wall.

Ventrally (fig.3) the floor of the pharynx is vaulted by the base of the tongue, so that roof and floor are closely approximated. In midsagittal section (fig.3,Ph.C.) or in cross-section the lumen appears as a thin crescentic slit.

The larynx (figs.1,2,3,Lr.) extends ventrally from the caudal portion of the pharynx and then turns caudally. In this embryo the larynx, when viewed in cross-section, resembles the letter "T", the crossbar of the letter being ventral and containing a small lumen. Just cephalad to the thyroid gland the larynx becomes more rounded and is continuous with the trachea (figs.1,2,3,Tr.).

2. <u>The first and second pouches</u>.--The first pharyngeal pouch as already mentioned has the appearance of a wing, arising from the dorsolateral margin of the pharynx and extending caudad and laterad

to end as a blind flattened pouch, the posterior tympanic recess (figs.2 and 4,P.T.R.). It is constricted at the base resembling more the condition found by Fox ('08) (his fig.29) in the 24 mm. pig than in his 20 mm. pig (his fig.23). To use the terminology of Hammar ('02) (for human) and Fox ('08) (for pig), the sulcus tubo-tympanicus (figs.2 and 4,S.T.T.) is continuous from the pharynx as the anterolateral margin of the first pouch, terminating at the dorsal apex (figs.2 and 4,D.Ap.) where it meets the sub-meckelian fold (S.M.F.) and the fold of the sulcus tensoris tympani. The sub-meckelian fold extends from the dorsal apex in a prominent fold on the ventrolateral side of the pouch. The sulcus tensoris tympani (figs.2 and 4,S.Ty.) terminates in the posterior tympanic recess (figs. 2 and 4, P.T.R.). From this point the posteromedial margin passes medially and cephalad as the posterior limit of the pouch. Meckel's cartilage lies in the angle between the first pouch and the vestibular fold. Cephalad it extends into the mandibular arch as a rod-shaped cartilage,while caudad it passes laterally above the sub-meckelian fold of the first pouch. The manubrial process from Meckel's cartilage pushes medially and causes the manubrial fossa (fig.2,M.F.) just ventrocaudad to the sub-meckelian fold. Just cephalad to the manubrial fossa the ectoderm (figs.2 and 4, Ect.) forming the external ear unites with the ventral surface of the first pouch (fig.2,Ent.I.).

The second pharyngeal pouch of the 20 mm. pig used in the present study is not joined with the first pouch as shown by Fox ('08) in a pig of the same length. But the second pouch (fig.4,T.F.) is seen to lie as the tonsillar fold on the lateral wall of the pharynx, being partially overhung by the posteromedial margin of the first pouch. According to Fox, this is the position of the tonsillar

lar fold in a 24 mm. pig.

3. The third pouch and the thymus.--The third pharyngeal pouch has become indistinct. The thymus in the 20 mm. pig examined had no connections with the pharynx or the ectoderm. It seems to correspond very closely to the description by Badertscher ('15). The cephalic end of the gland is somewhat lobulated in appearance and is situated at the level of the bifurcation of the common carotid artery. The superficial thymus (figs.1,2 and 4,S.Th.) of Kastschenko, or 'vesicula cervicalis lateralis' of Badertscher, hooks over the hypoglossal nerve by the connecting band described by the latter author. The thymic head (figs.1,2 and 4,Th.H.) is wedged in between the same nerve laberally and the bifurcation of the common carotid artery medially (figs.2 and 4,C.C.A.). Dorsad is the ganglion nodosum and the vagus nerve. Parathyroid III is probably fused on the dorsomedial side of the thymic head as described by Badertscher and others, but in my specimen no differentiation could be made at this stage. The intermediary cord is a solid slender cord leading caudad and slightly medially and ventrad from the head of the thymus (figs. 2 and 3,I.C.). At the level of the main mass of thyroid gland (figs. 2 and 3, Thr.G.), the thymus becomes enlarged and forms the mid-cervical segment described by Badertscher ('15). This swelling is higher and longer on the left side than on the right. It is connected below by the short cervico-thoracic cord (figs. 2 and 3, C.T.C.) to the thoracic segment (figs.1,2,3,T.S.). The thoracic segment of either side consists of a flattened irregular mass lying on the pericardial surface (fig.1). The thoracic segments of right and left sides are in close proximity but are not fused at this stage.

4. <u>The fourth pouch and the thyroid gland</u>.-- There is no evidence of the fourth pouch on the pharynx and the thyroid gland (fig.2,Thr.G.) is separated from the pharynx, lying as a single mass with two lateral processes (fig.2,L.Thr.). Dorsal to the gland is the trachea, laterodorsad the common carotid arteries, lateroventrad the mid-cervical segments of the thymus on either side. The lateral process on the right side is much the longer, extending well up on the side of the trachea to the larynx. This lateral process apparently represents the lateral anlage of the gland derived from the fourth pouch (fig.2,L.Thr.), together with parathyroid IV. This process on the left side is so short that it forms only a rounded bud on the cephalolateral aspect of the gland. The thyroid is much wider from side to side and its caudal margin is convex terminating in a rounded angle, while the cephalic margin of the gland is concave. The median portion of the gland is more open and vascular than the lateral portions.

## IV. TRACHEA AND LUNGS.

### a. Literature

No attempt will be made to give a complete review of the literature in this field as it has been dealt with very fully by Flint ('06), who studied the development of the lungs in pigs from the first anlage to the time of birth.

Flint's terminology, which has been adopted in this paper, requires a brief explanation. On the right side of the trachea above its bifurcation a tracheal bronchus is given off. This is the eparterial bronchus and is called by Flint 'right lateral one' (L.1). The trachea then divides into right and left stem bronchi. The first lateral branches of the stem bronchi are designated as 'lateral two' in the pig (L.2); the remaining lateral branches he designates 'lateral three', 'lateral four', etc. The dorsal, medial and ventral branches of the stem bronchi are then named according to their position on the stem bronchi, and the numerical number is accorded them which corresponds to their position with respect to the lateral series. The secondary branches of the lateral, medial, ventral and dorsal bronchi are named according to their position and direction of growth on the primary branches.

The terms 'superior' and 'inferior' are used by Flint as meaning cephalic and caudal, and are similarly used in my own observations.

Table 1.—The bronchial tree of an 18.5 mm. pig as shown by Flint (Amer. Jour. of Anat., Vol.6, p.51). L.1, L.2, L.3, etc. = the lateral series of bronchi. D.2, D.3, etc.= the dorsal series of bronchi. V.3, V.4, etc.= the ventral series of bronchi. M.4, M.5, etc.= the medial series of bronchi. ap.= apical branch of left L.2. m= Medial branch. d= Dorsal branch. l= Lateral branch. v= Ventral branch. s= Superior branch. i= Inferior branch. di= Dorso-inferior branch. li= Lateroinferior branch. vs= Ventro-superior, etc.

## Trachea

L.1

(1) di

(3) d-l

(2) vs

(3) ds-li

### Right Bronchus

L.2

(2) vi
(2) di

(2) li
(3) di-s-ds

V.2

(2) i
(2) vs
(2) vi

D.2

L.3

(2) d

V.3

D.3

(2) m

L.4

(2) v

D.4

V.4

L.5

D.5

V.5

### Left Bronchus

L.2

(2) Ap.
(3) d-l

(2) li
(3) ds-vi

D.2

(2) m

L.3

(2) d
(2) vs
(2) l

V.3

D.3

(2) m

L.4

(2) v
(2) ds

D.4

V.4

L.5

D.5

V.5

L.6

b. Observations

The trachea (figs.1,5 and 6) is a simple tube arising from the caudal extremity of the larynx and passing almost directly caudad to its bifurcation. It lies ventral to the oesophagus throughout its entire extent. The trachea becomes slender in its middle portion but increases gradually in size as it extends caudad to bifurcate into right and left stem bronchi.

The lungs of the 20 mm. pig observed by me are not essentially different from those of the pig at 18.5 mm. observed by Flint. The relations of the right lung will be considered first.

Lateral 1 on the right side (figs. 5 and 6, L.1) comes off from the trachea at nearly a right angle. It takes a lateral and slightly caudal direction, dividing finally into ventrosuperior (L.1,vs) and dorsoinferior (fig.6,L.1,di) divisions. Lateral 1 is eparterial. The dorsoinferior bronchus gives off near its origin a dorsal branch (fig.6,L.1,d) and more peripherally a lateroinferior bud (fig.6, L.1,li) terminating in the region of dorsal 2 (fig.6,D2). This relation Flint states persists throughout life. The ventrosuperior branch (figs.5 and 6, L.1,vs) extends to the apex of the lung giving off two small branches, a dorsal (fig.6,L.1,d) and lateroinferior (fig.5,L.1,li) while the main stem ends in a small rounded bud (fig.5,L.1,vs).

The trachea bifurcates into right and left stem bronchi (figs. 5 and 6, R.and L.,S.B.) and together with the trachea they present, as Flint suggests, a "wish-bone" appearance, the right being a little the longer and larger of the two. They arch laterally as they take a caudodorsal direction, being farthest apart in the neighborhood of lateral 4 (figs.5 and 6, L.4) and coming closer together at their terminations. The most ventral point of the axial tree is therefore the bifurcation of the trachea.

The right stem bronchus is seen to give off at the point of bifurcation lateral 2 (figs.5 and 6, L.2) which is the largest of the series. It extends transversely, arching ventrad, cephalad, and dorsad and then ventrad around the dorsal aspect of the heart and ending in a terminal swelling. Dorsad it gives origin to the prominent dorsoinferior (figs.5 and 6, L.2,di) branch. This branch is almost as large as the main trunk and in some cases (according to Flint) it may continue as the main trunk, in which case the ventroinferior branch becomes of secondary importance. The dorsoinferior branchus has two small buds (dorsosuperior and ventroinferior), which are situated almost opposite each other (not shown in figures). The main trunk takes a dorsoinferior and lateral direction being ventral to the dorsoinferior branch of lateral 1. Lateral 2 gives off five other branches. The largest of these is a ventroinferior (fig.5, L.2, vi), arising the same distance from the stem bronchus as the dorsoinferior branch just described. In line with the ventroinferior branch there are two other small inferior buds (fig.5,L.2, i and i'). Opposite i on the superior surface of lateral 2, there is a small ventral superior branch (fig.5,L.2,vs); there is also one small round superior bud (fig.5,L.2,s).

The next branch of the right stem bronchus is ventral 2, or the infracardiac bronchus (fig.5,V.2). This bronchus arises immediately below lateral 2 and passes caudoventrad, turning medially across the midline to end in large round terminal end bud. It gives rise to three branches. The first branch of ventral 2 is the ventroinferior (fig.5,V.2,vi), which is a long, slender branch and shows evidence of a dichotomous division at its end. The second branch is the small ventrosuperior branch of ventral 2 (fig.5,V.2,vs).

The third is the ventroinferior branch (fig.5,V.2,vi'), which has the appearance of being an unequal division of ventral 2.

Dorsal 2 (fig.6,D.2) of the right stem bronchus arises from the dorsal surface slightly cephalad to the level of lateral 3. It is constricted at its origin and increases gradually in size as it grows out. It presents one very small medial bud (fig.6,D.2,m) near its middle portion.

Lateral 3 (figs.5 and 6, L.3) is the next branch of the right stem bronchus. It is a short stout branch, descending slightly as it courses laterad. Near its middle portion it gives off two branches. The one (fig.6,L.3,d) is a large irregular bud arising from the dorsal surface, while opposite this on the ventral surface is to be seen a slender ventroinferior branch (fig.5,L.3,vi). In its termination lateral 3 gives off a large ventrosuperior bud (fig.5,L.3,vs) and a smaller inferior bud (fig.5,L.3,i), so that the end presents a double branched appearance.

Next in series is dorsal 3 (fig.6,D.3), situated half way between lateral 3 and 4. In appearance it is much the same as dorsal 2, having a large knob-like ending. It has one medial branch (fig.6,D.3,m) with a small bud-like end supported by a much constricted neck.

Ventral 3 (fig.5,V.3) originates a little caudad to the level of dorsal 3. It is a small, slender branch, coming off ventrad and then turning caudad at right angles to itself. It has no branches.

Lateral 4 (figs.5 and 6, L.4) takes a course directly laterad from the axial bronchus for a short distance, then it turns directly caudad, running parallel with the stem bronchus. At the place of bending it gives off a small dorsosuperior bud (fig.6,L.4,ds).

Medial 4 (figs.5 and 6, M.4) is represented by a large bud, situated at the same level as lateral 4. It is the first of the medial series to appear on the right stem bronchus.

Dorsal 4 (fig.6,D.4) is longer than medial 4 and situated a little caudad. It runs dorsocaudad and slightly medially. It is a slender bronchus presenting a mediosuperior bud (fig.6,D.4,ms) and corresponding in appearance to the remainder of the dorsal series.

Ventral 4 (fig.5, V.4) is next in series on the right stem bronchus. It is represented by a short branch, which extends ventrocaudad from the stem bronchus and has no branches.

Lateral 5 (figs.5 and 6, L.5) resembles lateral 4 but is smaller and has much the appearance of a hook. It has one very minute ventral bud (fig.5, L.5,v).

Medial 5 (figs.5 and 6, M.5), which is at approximately the same level as lateral 5, is a small pointed bud.

Dorsal 5 (fig.6, D.5) and ventral 5 (fig.5,V.5) are both small undivided buds much the same as medial 5, while lateral 6 (fig.5, L.6) shows merely as a thickening in the epithelium, producing a distinct swelling. Ventral 6 (fig.5,V.6) is present on the end of the primary bronchus as a small bud.

In describing the left side of the bronchial tree a detailed description will not be given as the condition is similar to that on the right side of the tree, and the reader is referred to figures 5 and 6 and table 2 for details. Only the differences in the main bronchi will be considered here. As stated above, no tracheal or eparterial bronchus is present on the left side. The apical bronchus (figs.5 and 6,ap.) arises as the first branch of lateral 2 (figs.5 and 6, L.2) and has one large dorsoinferior branch (fig.6,L.3,di). According to Flint ('06) the left apical bronchus is homologous to the dorsoinferior branch of lateral 2 (fig.6,L.2,di) on the right side. Their appearance here suggests this possibility. Excepting this difference, left lateral 2 has much the same appearance as right lateral 2. Ventral 2 and dorsal 2 are both absent on the left stem bronchus. Dorsal 3 (fig.6,D.3) is at a higher level and more strongly developed than its fellow of the right side. Its terminal branch seems to show a dichotomous division. Ventral 3 is misplaced so that ventral 4 may be considered as represented by two bronchi (fig.5,V.4,4'). Lateral 4 (figs.5 and 6,L.4) and medial 4 (fig.6,M.4) are relatively higher on the stem bronchus than their homologous branches on the right side. Medial 5 and ventral 5 of the left side are both absent. Lateral 5 (figs. 5 and 6, L.5) is much larger than the corresponding branch of the right side. Lateral 6 (figs.5 and 6, L.6) is a distinct bud as contrasted to the rounded prominence of lateral 6 on the right stem bronchus.

Table 2. -- The bronchial tree tabulated from a 20 mm. pig as shown by Born's reconstruction method. The abbreviations are the same as in table 1.

Trachea

L.1

(2) di
  (3) d
  (3) li
(2) vs (Apical)
  (3) d
  (3) li

Right Bronchus

L.2

(2) di
  (3) ds-vi

(2) vi
(2) i (two)
(2) vs
(2) s

Left Bronchus

L.2

(2) Ap
  (3) di
    (4) i
(2) vi
(2) ds
(2) vi'

V.2
(2) vs
(2) vi (two)

D.2
(2) m

L.3
(2) d
(2) vi
(2) i
(2) vs

D.3
(2) m

V.3

L.4
(2) ds (Unequal dichotomy)

M.4

D.4
(2) ms

V.4

L.5
(2) v

M.5

D.5

V.5

L.6

V.6

L.3
(2) d
(2) v
(2) vs
(2) i-s Terminal, dichotomous division.

D.3
(2) m
(2) ds

L.4
(2) s ) unequal
(2) i ) division

M.4

D.4
(2) ds

V.4 (dichotomous division at end)

V.4'

L.5
(2) s

D.5

L.6

V.6

By comparing table 2 of the bronchial tree in the 20 mm. pig with table 1 of Flint's ('06) tabulation of the bronchial tree of an 18.5 mm. pig, it will be seen that the two are very similar, but the 20 mm. pig shows a few advances. The lateral series of the right stem bronchus as shown by Flint (table 1,L.1,to 5 inclusive) are slightly less complicated than in the 20 mm. pig (table 2,L.1 to 6 inclusive) and the sixth lateral bronchus has appeared which was not present in the 18.5 mm. stage. On the left side the same number of lateral branches are present in both cases, the only difference being that the 20 mm. pig (table 2,L.2 to L.6) show a few more secondary branches. The ventral series on the right stem bronchus as shown by Flint (table 1,V.2 to 5 inclusive) consists of V.2,V.3,V.4, and V.5. In addition to this in the 20 mm. pig, we have ventral 6 (table 2,V.6). On the left stem bronchus there is likewise present ventral 6, which was not present in Flint's 18.5 mm. pig. Ventral 3 (table 2, and fig.5,V.4) is misplaced giving a double ventral 4 in my 20 mm. pig. Flint shows dorsal 2, dorsal 3, dorsal 4 and dorsal 5 (table 1, D.2 to D.5 inclusive) on both the right and left stem bronchi, while in my 20 mm. pig (table 1, D.2 to D.5 inclusive) the condition is the same excepting the absence of dorsal 2 on the left side. Flint's table shows no medial branches from the stem bronchi on either side, while my 20 mm. pig shows medial 4 and medial 5 on the right side (table 2, M.4 and M.5) and medial 4 on the left side (table 2,M.4). The differences of the secondary branches are hardly worthy of mention, as the more numerous branchings in the 20 mm. pig would naturally be expected. The other variations just mentioned are not surprising, because as Flint states the medial primary bronchi are extremely variable both as to position and number and may be absent entirely as he finds in this one example. The same may be said of the dorsal and ventral primary bronchi, but Flint finds these to be more constant than the medial series. The lateral branches of the bronchial tree, according to Flint, are fairly constant.

The blood vessels of the lungs have a rather characteristic arrangement. The pulmonary artery (fig.5,P.A.) is situated ventral to the trachea and divides a short distance cephalad to the tracheal bifurcation into right and left pulmonary branches. On the right side (figs.5 and 6,R.P.A.) this artery passes under (caudal to) the tracheal bronchus (figs.5 and 6, L.1) and continues dorso-laterad to the stem bronchus, giving off branches which correspond to the branches of the bronchi. On the left side, on account of the absence of bronchus lateral 1, there is no corresponding artery, and the apical branch of the artery is dorsal to the bronchus in contrast to its ventral position on the right side.

The pulmonary veins arise near the ends of the right and left axial bronchi and those from the right and left sides unite just caudad to the bifurcation of the trachea to form a single trunk. The trunk (fig.5,P.V.) thus formed is situated on the left stem bronchus, receiving a relatively prominent tributary from left lateral 3. Just cephalad to the bifurcation of the trachea right and left tributaries from lateral 2 of each side empty into the pulmonary vein. A small vein descending from the ventral region of the trachea joins the vein from right lateral 1 to form a common trunk, which empties with the vein from right lateral 2 into the main trunk of the pulmonary vein.

In general the branches of the blood vessels correspond to the branches of the bronchi, the veins lying ventro-medially, while the arteries are placed dorsolaterad to the bronchi, the ventro-dorsal arrangement being vein, bronchus and artery.

## V. OESOPHAGUS

Concerning the oesophagus there is little to be said as the condition at this stage is fairly simple and few questions of developmental importance are presented.

### a. Literature

See note (d) page 44a.

Johnson ('13) in studying the form of the mucosa present in the different developmental stages of human embryos finds in a 19 mm. embryo that the oesophagus contains numerous small vacuoles in its walls, but that the lumen is continuous throughout. He states that this confirms the work of Frossner ('07) and Schridde ('08), but that Schridde denies the presence of vacuoles and describes epithelial bridges. In a human embryo of 22.8 mm. Johnson describes three folds in the oesophagus, one ventral in the cephalic part of the tube which is the continuation of the ventral fold of the pharynx, a second dorsal and in mid-region, and a third fold in a left lateral position just cephalad to the stomach.

### b. Observations

The oesophagus in the 20 mm. pig is a simple tube arising from the caudal end of the pharynx (figs.1,2,3, Oe.) extending caudad and slightly dorsad in a gentle curve, then turning ventrad between the two axial bronchi and continuing caudad to reach the stomach (fig.1). It possesses only one fold, which is a ventral fold continuous with the ventral fold of the pharynx and terminates in the mid-oesophageal region. The cephalic portion of the oesophagus is therefore crescentic in cross-section. Near the mid-region the oesophagus apparently turns about its axis through an angle of ninety degrees and becomes compressed from side to side, possessing a slit-like lumen which is directed ventrodorsad. The vagi along the cranial end of the oesophagus are situated ventrolaterad to the oesophagus. However, near the beginning of the caudal third, they come to lie closer to the oesophagus, the right nerve passing dorsad to the oesophagus, while the left nerve lies on the lateral side. Together they form a plexiform arrangement between the two main trunks and surrounding the oesophagus. Caudal to the plexus the nerves become two separate trunks the left passing to the right ventral margin of the stomach while the right nerve passes to the right of the stomach and dorsad (figs.7 and 8, R.V. and L.V.).

The epithelial wall of the oesophagus is thin, consisting of two or three rows of low columnar cells. There are numerous vacuoles present (fig.15,vc.), some of which connect with the lumen of the tube, while others are embedded in the epithelial wall. It was noted that the vacuoles are more numerous in the cephalic third of the tube, there being only three or four in the caudal end of the oesophagus. There is no bridging of the tube and the lumen is continuous throughout, as found by Johnson ('13) in the human at 19 mm.

## VI. STOMACH

### a. Literature

The literature, so far as noted, contains no observations upon the stomach of the pig near the 20 mm. stage.

### b. Observations

The stomach (figs.1,7,and 8, St.) of the 20 mm. pig is a widely dilated portion of the alimentary tract, situated on the left side of the median plane and in close relation with the dorsal pancreas (figs.1,7,and 8,D.Pan.). The right vagus nerve (fig.7, R.V.) lies mediodorsad to the right side of the stomach and ramifies between the stomach and the dorsal pancreas. The left vagus nerve (fig.7, L.V.) is situated on the ventral surface of the stomach along the right margin. The stomach at this stage presents ventral and dorsal surfaces, and right and left margins (lesser and greater curvatures). The surfaces are somewhat flat and irregular, but this condition as seen in wax models is doubtless exaggerated by the fixation process, as in fresh embryos the surfaces appear rounded.

The fundus of the stomach is very prominent, and shows a marked diverticulum (figs.1 and 8, G.D.) as observed by Lewis ('03) in a 12 mm. pig. This diverticulum assumes the form of a blind pouch which shows a marked constriction at its place of origin from the stomach.

Figure 12 shows numerous gastric pits (pt.) on the internal surface of the stomach, somewhat similar to those described by Johnson ('10) in a 19 mm. human embryo. They show no corresponding outpouchings on the mesenchymal surface. No vacuoles are present. From this stage alone it is impossible to determine the significance of the pits, but they probably represent the anlages of the gastric crypts.

## VII. PANCREAS

### a. Literature

Walssow ('95) finds the ventral pancreas in a pig of 8.7 mm., and describes it as a bilobed anlage arising from the ductus choledochus. The left lobe disappears while the right lobe grows and unites with the dorsal pancreas.

Völker ('02) describes a bilobed dorsal pancreas arising from the left lateral surface of the intestinal wall and a bilobed ventral anlage arising from the common bile duct. He fails to give either the age or length of the pig embryos studied, but since he found the dorsal and ventral pancreas growing around the omphalomesenteric vein to unite with each other, this would suggest (according to the work of later authors) that he observed pigs near the 20 mm. stage. He describes also a case of an accessory dorsal pancreas. Furthermore he finds that the two pancreatic ducts may unite where they cross ventral to the vein.

Thyng ('08), in describing a number of wax reconstructions of the pancreas in different mammals, figures the pancreas of a 20 mm. pig (Amer. Jour. Anat., Vol. VII, p.491, fig.2). He describes the gland as consisting of a large dorsal pancreas arising from the dorsal surface of the duodenum and lying on the left side of the vitelline vein, while the ventral pancreas in the same specimen is still connected by its duct to the ductus choledochus and passes to the right of the vein. Thyng finds that the dorsal pancreas sends a process to the right to unite with the ventral pancreas dorsal to the vitelline vein. In a 20 mm. pig he finds ~~that~~ the two glands in apposition at this point but not fused. In a 24 mm. pig the ventral duct has lost its connection with the common bile duct.

Lewis ('11) finds a cyst in the mesenteric attachment of the liver of a 20 mm. pig. He reports nodules or cysts in pigs of various lengths and thinks that although most of them are of hepatic origin, part of them arise as accessory pancreases, or at least are of pancreatic origin.

b. Observations

In the 20 mm. pig (H.E.C.1702) the pancreas has two distinct lobes, a dorsal (fig.7 and 8, D.Pan.) and a ventral (fig.7, V.Pan.). The dorsal pancreas is situated dorsad and to the left of the omphalomesenteric vein (fig.7, O.V.), with the right vagus nerve (fig.7, R.V.) separating it from the stomach wall. The hepatic artery (fig.7, H.A.) and the splenic vein (fig.7, S.V.) pass just cephalad to the dorsal pancreas, the gland itself taking for the most part a craniocaudal direction. Dorsal to the omphalomesenteric vein, the dorsal pancreas sends out a process (fig.7,y) toward the ventral pancreas (fig.7,V.pan.); but there is not fusion at this point and as yet the two are not even in apposition here. The dorsal pancreas possesses a single duct (figs.7 and 9,D.D.Pan.) with a definite lumen, arising from the left dorsal margin of the duodenum (figs.7 and 9, du) caudal to the common bile duct. From the place of origin the dorsal duct turns ventrad to the left and slightly cephalad, then makes a bend to the left and dorsad, still maintaining its cephalic direction until it joins the main part of the dorsal anlage. It is not a distinct duct except at its origin, but soon shows branching and anastomosing cords and the lumen becomes uncertain. The duct is in close apposition to the left side of the omphalomesenteric vein. It is also in apposition with the caudal surface of the ventral pancreatic duct (figs.7 and 9, D.V.Pan) where the two ducts cross, but an actual union seems doubtful. As is well known, the dorsal pancreatic duct alone persists in the adult pig.

The ventral pancreas (fig.7,V.Pan) is smaller than the dorsal anlage, being situated dorsad and to the right of the omphalomesenteric vein and in close proximity to it between the vein and the dorsal surface of the duodenum (fig.7, Du.). In this specimen the ventral pancreas has two ducts (figs.7 and 9, D.V.Pan), both of which, though in close proximity to the ductus choledochus, (figs. 7 and 9, D.C.) have no connection with it, but terminate blindly. Both ducts pass dorsad and to the right, just cephalad to the duct of the dorsal pancreas, and become indistinct in the main mass of the ventral pancreas, but are entirely separate before reaching the gland. The two ducts may possibly represent the ducts of the two portions of the bilobed ventral anlage, which have lost their primitive connection with the ductus choledochus.

Because of the anomalous condition of the ventral ducts in this specimen (H.E.C.1702) the pancreatic ducts were modelled in a second specimen of the same length (from the Missouri Embryological Collection) shown in figure 10. The dorsal duct (D.D.Pan) was found as in the first specimen, while the duct of the ventral pancreas (D.V.Pan) consists of a single duct running ventrad and slightly craniad from the main mass of the ventral pancreas, similar to the ducts found in the first specimen, but showing no evidence of being paired. The single duct of the ventral pancreas terminates blindly a short distance from (but independent of) the ductus choledochus (fig.10). In the second specimen the duct of the dorsal pancreas (duct of Santorini) and the duct of the ventral pancreas (duct of Wirsung) were not in apposition. The two gland bodies were in apposition dorsad to the omphalomesenteric vein but had not fused, the condition noted by Thyng ('08) in a 20 mm. pig.

Two other 20 mm. pigs, from the Minnesota collection, were studied and no trace of a double ventral duct could be found; but in every case the ventral duct terminated blindly and had no connection with the common bile duct.

No special observations were made on the liver, but the gall bladder and its ducts were modelled and figured. The ductus choledochus (figs.7, 8 and 9, D.C.) arises from the ventral side of the duodenum and takes a course cephalad arching slightly dorsad and then turning sharply ventrad and passing caudad into the ventral mesentery of the liver (fig.1). Here it ends in the neck of the pouch-like vesica fellea (figs. 1 and 7, G.B.). At the point where the cystic duct turns ventrad a number of small hepatic ducts are seen to join it. These appear to be in a right and a left group (fig.9, R.H.D., and L.H.D.). In the region of the hepatic ducts two cystic nodules were found, one of which is shown in figure 9 (c). This cyst-like structure was located in the ventral mesentery just dorsad to the hepatic ducts and is a hollow irregular, epithelial structure. The similarity of its epithelium to that of the biliary ducts would suggest that it is of hepatic origin. Lewis ('11) figures a like structure in a 20 mm. pig (his fig.12). The other cyst is not shown in my figures, but was similar to the one just described, though much smaller, being about 64 micra in diameter.

## VIII. LARGE AND SMALL INTESTINES

### a. Literature

MacCallum ('01) studied the intestine of pigs varying from 12 mm. to 12 cm. in length and finds in an embryo of 18 mm. that the caecum is present on the rectal end of the umbilical loop of the intestine. Nearly half of the gut at this stage is in the extra-abdominal coelom. Just inside the body cavity proper the small intestine shows a beginning loop (his fig.2). In addition to this in the 23 mm. pig he finds that one loop has formed.

Lewis and Thyng ('08) studied the occurrence of intestinal diverticula in embryos of the pig, rabbit and man. In pig embryos from 14 to 24 mm. they find numerous diverticula along the course of the small intestine, but record only one case where they were present in the large intestine. In regard to such structures, these authors state that the diverticula "begin as round knobs which may become elongated and detached from the intestine in the form of nodules, strands or cysts. In later stages they acquire a lumen and those found in the distal part of the small intestine appear as flask-shaped gland-like pockets."

Elze ('09) studied the intestinal diverticula in a number of pigs ranging from 8.2 mm. to 14.4 mm. in length. He describes the diverticula in the duodenum as "Sprossen" and finds them only along the line of mesenteric attachment. In the lower part of the small intestine, Elze describes the diverticula as "Knospen" and states that they are opposite the mesenteric attachment. Those of the jejunum and ileum he thinks are more numerous, have a wider range and are larger. According to Elze, intestinal diverticula grow aborally.

Johnson ('10) in his work on human embryos finds both vacuoles and diverticula in the small intestine of a 19 mm. embryo. To quote this author: "The vacuoles of the oesophagus, stomach and duodenum, and the pockets of the duodenum, jejunum and ileum are related structures. They are all the result of a similar process of growth; which for undetermined reasons manifests itself differently in the different parts of the digestive tube."

See note (e) page 44a.

Johnson ('14) describes the rectum in a human embryo of 19 mm. as being a simple tube with two swellings; the larger upper one he terms the "bulbus analis recti" and the lower smaller one the "bulbus terminalis recti". These two swellings are compressed dorsoventrally, and in a 22.8 mm. human there is a shallow infolding on their ventral surface which he regards as the first appearance of the rectal columns.

## b. Observations

1. General relations.-- The intestine in the 20 mm. pig as shown by graphic reconstruction and dissections in figure 1, is seen to be a simple tube-like structure just beginning to form loops and

coils. A large portion of the intestine is thrown out in the umbilical cord as a simple U-shaped loop. Upon re-entering the body, the intestine runs almost directly dorsad, but in the duodenal region turns caudad and finally terminates in the rectal swelling (fig.1,R.). On the caudal segment of the umbilical loop, a short distance from the attachment of the yolk stalk can be seen the outgrowing, blind caecal diverticulum (fig.1,Cae). This marks the ileo-caecal junction. Looking dorsad from the yolk-stalk (fig.1, Y.S.) the small intestine will be seen to lie parallel with the large intestine, but after it enters the body cavity proper, the small intestine forms two loops. A glance at figure 1 will show that one of these loops is just beyond the duodenal region and a second is near the caudal end of the liver. Thus the intestine appears to be a little more advanced in development than that of the 18 mm. pig observed by MacCallum.

2. The form of the mucosa and size of the intestinal lumen.-- The terms applied by various authors to structures found in the small intestine will be used according to the following definitions:

A "bud" is an outgrowth of epithelium from the intestinal wall, either solid or having a lumen not connecting with that of the gut. A "diverticulum" is a proliferation or outgrowth from the intestinal epithelium, having a lumen continuous with that of the intestine. A "vacuole" is a small cavity in the epithelial wall of the digestive tube.

The small intestine of the 20 mm. pig (H.E.C.1702) shows 13 distinct epithelial outgrowths. Four of these possess distinct connections with the intestinal lumen and are classified as diverticula. Nine have no connecting lumina and are called buds. Figure 11 shows a portion of the duodenum (just below the entrance of the common bile duct) with four outgrowths. The duodenum has in all six outgfowths, three of which are diverticula and three buds. All of them are opposite the mesenteric attachment, and are small and pointed or bud-like in appearance. The six buds of the remaining small intestine are situated in the upper half of the tube or in the jejunal region. They are opposite the mesenteric attachment and are more rounded and blunter than those of the duodenal region. Figure 13 shows a reconstructed section of the jejunum where a bud (b) is split longitudinally. This outgrowth contains a lumen or a vacuole, but there is no connection with the lumen of the gut.

One detached nodule was noticed lying just outside the circular muscle layer in the upper jejunal region. It is a hollow sphere about 48 micra in diameter.

No diverticula other than the caecal bud were found in the large intestine or rectum.

The duodenum contains two vacuoles. They are quite numerous in the jejunal region, as shown in figure 13, but are absent in the large intestine.

The lumen of the intestine is continuous throughout from the stomach to the anal aperture. The lumen is very small in the mid-portion of the small intestine (fig.13), but larger in the duodenal region(fig.11). It decreases in size as it passes to the jejunum, where it is almost occluded, the walls becoming irregular (fig.13). In the lower part of the small intestine the lumen becomes small and uniform (fig.14) and the epithelial walls are thick and regular. In the large intestine the epithelium becomes thin and the lumen larger and slightly sacculated.

3. Rectum. The rectum is compressed laterally, the ventro-dorsal diameter thus being the greater. Johnson ('14) found the

rectum in human embryos between 17 and 22.4 mm. to be compressed dorsoventrally. The model of the rectum shown in figures 17 and 18 is seen to have two distinct swellings. The more cephalic swelling is the larger and shows a distinct dorsal infolding (fig.17,D.F.). The cephalic swelling decreases gradually in size as it passes to the colon; caudally it terminates abruptly by an external constriction. Opposite the constriction, there appears on the internal surface a crescentic projection (fig.17,Pr.) on the right dorsal half of the tube. The significance of this epithelial ledge is uncertain.

The caudal swelling of the rectum is short, being marked off above by the constriction and ledge just described, and terminating below at the external aperture. At this place the lumen shows a second transverse ledge (Pr.'), possibly the remains of the anal membrane. Observations have not been made to determine the later history of these two swellings; but they may correspond to the 'bulbus analis recti' and the 'bulbus terminalis recti' described by Johnson ('14) in human embryos of about the same length.

SUPPLEMENT.

(a) Minot ('11) describes briefly the relations of the mouth cavity in the 20 mm. pig, shown in his figures 212,219,220, and 221 (mouth wrongly labelled pharynx in latter figures). The dental ridges are shown (unlabelled) in his figure 212.

(b) Minot ('11) describes briefly the nasal cavity of the 20 mm. pig, the nasoturbinals, maxilloturbinals and Jacobson's organs, etc., being shown in his figures 212,219 and 220. The anlages of the lateral nasal gland and nasolacrimal duct are apparently shown (unlabelled) in his figure 212.

(c) Minot ('11) figures the pharyngeal bursa in a 12 mm. pig (his figure 173) and again shows a similar (unlabelled) structure in a sagittal section of a 24 mm. pig (his fig.224).

(d) Minot ('11) in a transverse section through the neck of a 17 mm. pig shows the oesophagus to be compressed dorso-ventrally (his fig.208). In a similar section from a 20 mm. pig (his fig.213) may be seen in addition to this a distinct ventral infolding.

(e) Minot ('11) finds no folds or glands inside the intestinal canal of the 17 mm. pig. He notes that the rectum is still joined to the allantois at the cloaca. In the 20 mm. pig he figures the gut cut in four places in sagittal section (his fig.218) and states that it forms a number of coils. His figure 216 shows the rectum at this stage compressed dorsoventrally with a ventral infolding.

SUMMARY

The more important points observed on the epithelial portion of the digestive and respiratory tracts of the 20 mm. pig embryo may be briefly summarized as follows:

1. The vestibule of the mouth is represented by the prominent vestibular fold which presents on its dorsal surface the superior dental ridge and on its ventral surface the corresponding inferior dental ridge.

2. The salivary glands are represented by three anlages. The parotid anlage is a solid epithelial cord arising from the oral epithelium caudodorsad to the commissure of the lips and extending caudad. The anlage of the right side divides near its middle portion into three cords which immediately reunite. The anlage of the left side in a corresponding position presents merely a bulb-like swelling.

Of the three anlages, the submaxillary is the more advanced. It arises as a solid cord from the lingual sulcus and terminates in a gland mass just ventral to the first entodermal pouch.

The short cord-like anlage of the sublingual gland is connected to the lingual sulcus by a small epithelial plate in common with the submaxillary anlage.

3. The elongated irregular nasal cavity presents three ethmoturbinals, a nasoturbinal and a maxilloturbinal.

The lateral nasal gland is represented by a small tube-like anlage connected with the cephalic (anterior) portion of the middle meatus.

The simple tube-like anlage of the nasolacrimal duct is lightly fused with the dorsal margin of the inferior meatus, ending blindly both cephalad and caudad.

Jacobson's organ is a small blind pouch arising from the septal wall of the nasal epithelium.

4. The pharynx presents two entodermal pouches. The first entodermal pouch on its ventral surface is fused with the ectoderm and shows a marked constriction at its base. The second pouch is less prominent, appearing as the tonsillar fold on the lateral margin of the pharynx.

The pharyngeal bursa appears as a small blind outpouching from the dorsal and caudal portion of the pharyngeal wall.

The thymus has no connection with the pharynx or the ectoderm. The right and left thoracic segments are not fused but lie in close proximity on the surface of the pericardium.

The thyroid gland is a single mass lying ventral to the trachea.

The lateral elements (including parathyroid IV) derived from the fourth pouch are still distinguishable.

5. The bronchial tree presents a slightly more complicated condition than that shown by Flint in an 18.5 mm. pig.

6. The oesophagus is a simple tube throughout, presenting a single dorsal fold. Its wall contains numerous vacuoles but there is no bridging or obliteration of the main lumen.

7. The fundus of the stomach has a prominent diverticulum. The internal surface of the stomach presents a few small pits.

8. The dorsal and ventral pancreatic anlages are not fused, but (in one of the four specimens examined) their ducts are in apposition at the place of crossing. The duct of ventral pancreas has lost its earlier connection with the ductus choledochus. In one specimen this duct appears double. The duct of the dorsal pancreas opens into the dorsal side of the duodenum caudad to the opening

of the common bile duct.

9. In addition to the umbilical loop, the small intestine, a short distance beyond the duodenum, presents two loops. The epithelial wall exhibits numerous buds and diverticula. In the duodenal region they are along the line of mesenteric attachment, while in the remaining portions they are opposite the mesenteric attachment. Vacuoles are numerous in the jejunal region, but less common elsewhere. The lumen is very irregular but continuous throughout.

10. The caecum is present as a small blind pouch on the umbilical loop of the gut. The large intestine shows no loops or coils. Its lumen is slightly sacculated but patent throughout. The rectum is compressed laterally, ~~with~~ has a dorsal fold and presents two swellings. A transverse crescentic ridge on the internal surface marks the external constriction between the two swellings.

A second ridge in the caudal part of the rectum may represent the remnant of the earlier anal plate.

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# EXPLANATION OF FIGURES

The following abbreviations are used in figures 1 to 18:

A.L.F., Alveolo-lingual fold

Ao., Aorta

ap., Apical branch of bronchus left lateral 2.

A.T., Area of tongue

b, Bud

c, Cyst

Cae., Caecum

C.C.A., Common carotid artery

C.D., Cystic duct

Ch., Primitive choana

C.L., Commissure of lips

C.O., Concha obtecta

C.T.C., Cervico-thoracic cord of thymus

d, Diverticulum

d, d', Dorsal secondary bronchi

D.2,3, etc. Dorsal series of primary bronchi

D.Ap., Dorsal apex of first pouch

D.C., Ductus choledochus

D.D.Pan., Duct of dorsal pancreas

D.F., Dorsal fold of rectum

di, Dorsoinferior secondary bronchi

D.Pan., Dorsal pancreas

D.P.G., Duct of parotid gland

ds, Dorsosuperior secondary bronchi

D.S. L.G., Duct of sublingual gland

D.S.M.G., Duct of submaxillary gland

Du., Duodenum

D.V.Pan., Duct of ventral pancreas

D'.V.Pan., Duct of ventral pancreas

Ect.I., Ectoderm connecting with first pharyngeal pouch

E.O., External opening of rectum

Ent.I., First entodermal pouch of pharynx

Et.I,II,III., Ethmoturbinals

G.B., Gall-bladder

G.D., Gastric diverticulum

H.A., Hepatic artery

H.E.C., Harvard Embryological Collection

Hy., Hypophysis

i,i', Inferior secondary bronchi

I.C., Intermediary cord of thymus

I.D.R., Inferior dental ridge

I.M., Inferior meatus

J.O., Jacobson's organ

k, Rounded knob of vestibular fold

L.1,2,3, etc. Lateral series of primary bronchi

L.B., Lung buds

L.H.D., Left hepatic duct

li,li', Lateral inferior secondary bronchi

L.L., Lower lip

L.P.A., Left pulmonary artery

Lr., Larynx

L.S., Lingual sulcus

L.S.B., Left stem bronchus

L.Thr., Lateral thyroid gland

L.V., Left vagus

M., Mouth

m, Medial secondary bronchi

M,3,4,etc. Medial series of primary bronchi

M.C., Mouth cavity

M.C.S., Mid-cervical segment of thymus

M.F., Manubrial fossa

M.M., Middle meatus

Mo.E.C., Missouri Embryological Collection

N., Nose

N.A., Nares

Nc., Notochord

N.L.D., Nasolacrimal duct

N.T., Nasoturbinal

Oe., Oesophagus

O.M., Opening of mouth

O.V., Omphalomesenteric vein

p',p", Rounded prominences on vestibular fold

P.A. Pulmonary artery

P.B.S., Posterior blind sac

Ph., Pharynx

Ph.B., Pharyngeal bursa

Ph.C., Pharyngeal cavity

Pr., Crescentic projection on internal surface of rectum

Pr', Ledge-like projection on internal surface of rectum

pt., Pits on internal surface of stomach

P.T.R., Posterior tympanic recess

P.V., Pulmonary vein

R., Rectum

R.H.D., Right hepatic duct

R.F., Recessus frontalis

R.I., Recessus inferior

R.P.A., Right pulmonary artery

R.S.B., Right stem bronchus

R.V., Right vagus

S.D.R., Superior dental ridge

S.M.F., Sub-meckelian fold

S.M.G., Submaxillary gland

S.Pi., Sinus piriformis

St., Stomach

S.Th., Superficial thymus

S.T.T., Sulcus tubo-tympanicus

S.T.Ty., Sulcus tensoris tympani

S.V., Splenic vein

T.F., Tonsillary fold

Th., Thymus

Th.H., Thymic head

T.S., Thoracic segment of thymus

Thr.G., Thyroid gland

Tr., Trachea

U.L., Upper lip

V. 2,3,4,etc., Ventral series of primary bronchi

v,v', ventral secondary bronchi

Vc., Vacuole

V.F., Vestibular fold

vi,vi', ventroinferior secondary bronchi vs, ventrosuperior secondary bronchi

x, Swelling on left parotid duct

x', Division point of right parotid duct

y, Process of dorsal pancreas growing to the right

Y.S., Yolk-stalk

Z, Crest-like projection on lingual sulcus

Fig.1. A graphic reconstruction of the digestive and respiratory tracts of a 20 mm. pig embryo (H.E.C.1702). All structures are viewed in profile from the left side. The digestive and respiratory tracts are shaded. The umbilical loop of gut beyond the line a-b is drawn from a dissection. X 29.

Fig. 2. A photograph (retouched) of a wax model by Prof. F.P.Johnson (reconstructed by Born's method) of the epithelial wall of the nose, mouth and pharynx of a 20 mm. pig embryo (H.E.C. 1702). Viewed from the left side. X 70, reduced 5/8.

Fig. 3. A photograph (retouched) of a wax model by Prof. F.P. Johnson (reconstructed by Born's method) of the left nasal cavity, left half of mouth, and left half of pharynx as far caudad as the larynx (20 mm. pig, H.E.C.1702). The trachea, oesophagus and caudal part of pharynx are shown as a whole. A portion of same model shown in figure 2. X 70, reduced 5/8.

Fig. 4. A photograph (retouched) of a wax model by Prof. F.P.Johnson (reconstructed by Born's method) of the nose, mouth and pharynx of a 20 mm. pig (H.E.C. 1702), as seen from a dorsal view. The same model as shown in figure 2. X 70, reduced 5/8.

Fig. 5. A photograph (retouched) of a wax model (reconstructed by Born's method) of the bronchial tree of a 20 mm. pig embryo (H.E.C. 1702), ventral view. X 70, reduced 2/3.

Fig. 6. A photograph (retouched) of a wax model of the bronchial tree of a 20 mm. pig embryo (H.E.C. 1702). Dorsal view of same model as shown in figure 5. X 70, reduced 2/3.

Fig. 7. A photograph (retouched) of a wax model (reconstructed by Born's method) of the stomach, pancreas and gall-bladder from a 20 mm. pig embryo (H.E.C. 1702) viewed from right side. X 70, reduced 3/5.

Fig. 8. A photograph (retouched) of a wax model (reconstructed by Born's method) of the stomach, pancreas and gall-bladder of a 20 mm. pig embryo (H.E.C. 1702). The same model as shown in figure 7, viewed from the left side. X 70, reduced 3/5.

Fig. 9. A photograph of a wax model (reconstructed by Born's method) of the pancreatic and cystic ducts of a 20 mm. pig embryo (H.E.C.,1702), viewed from right side. X 250, reduced 3/5.

Fig. 10. A photograph (retouched) of a wax model (reconstructed by Born's method) of the pancreatic ducts of a 20 mm. pig embryo (Mo.E.C.) viewed from the right side. X 250, reduced 3/5.

Fig. 11. A photograph (retouched) of a wax model of a part of the duodenum of a 20 mm. pig embryo (H.E.C.,1702), showing three diverticula (d) and one bud (b) along the line of mesenteric attachment. Viewed from right dorsal side. X 200, reduced 1/2.

Fig. 12. A photograph (retouched) of a wax model(reconstructed by Born's method) from a portion of the ventral epithelial wall of the stomach of a 20 mm. pig (H.E.C.,1702). View of internal surface, showing pits (pt.). X 333, reduced 1/2.

Fig. 13. A photograph (retouched) of a wax model (reconstructed by Born's method) of the epithelial wall from the lower jejunal region of the gut of a 20 mm. pig embryo (H.E.C.,1702). The model is opened longitudinally showing internal surface. A vacuole (vc) is shown in a bud (b). X 200, reduced 7/12.

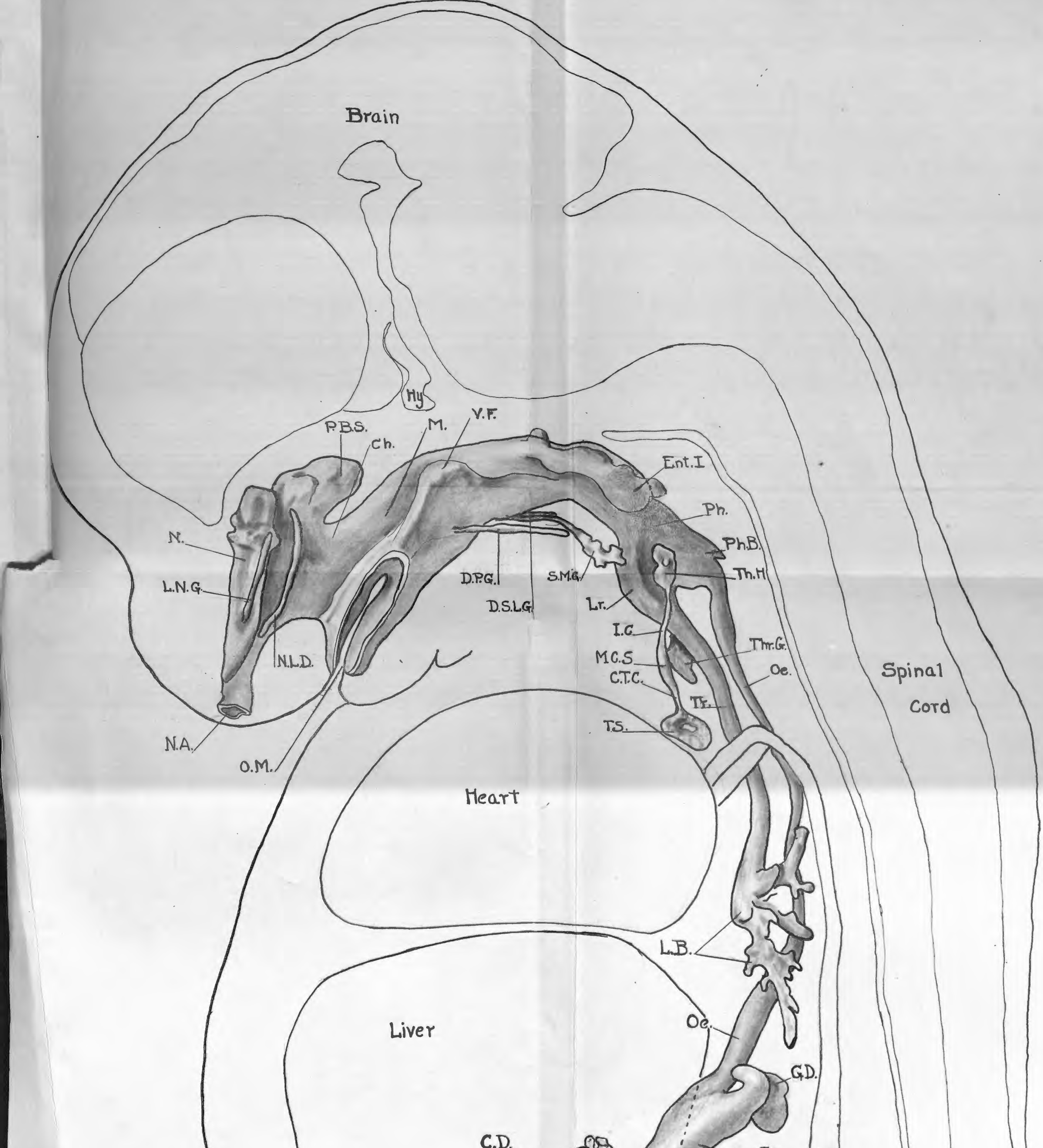
Fig. 14. A photograph (retouched) of a wax model (reconstructed by Born's method) of the epithelial wall of the ileum from the umbilical loop of the gut of a 20 mm. pig (H.E.C.,1702). Opened longitudinally to show internal surface. X 200, reduced 7/12.

Fig. 15. A photograph (retouched)of a wax model (reconstructed by Born's method ) of the epithelial wall of the oesophagus of a 20 mm. pig embryo (H.E.C.,1702) from the upper one-third of tube. The model is opened longitudinally showing vacuoles (vc) and the internal surface. X 200, reduced 7/12.

Fig. 16. A photograph (retouched) of a wax model(reconstructed by Born's method) of the epithelial wall of the colon from the umbilical loop of the gut, of a 20 mm. pig embryo (H.E.C.,1702). The model is opened longitudinally showing internal surface. X 200, reduced 7/12.

Fig. 17. A photograph (retouched) of a wax model(reconstructed by Born's method) of the epithelial wall of the right side of rectum of a 20 mm. pig embryo (H.E.C.,1702) showing projections (pr.,pr'.) into lumen, rectal swellings and external orifice (E.O.). Opened so as to show the internal surface. X 200, reduced 3/5.

Fig. 18. A photograph (retouched) of a wax model(reconstructed by Born's method ) of the epithelial wall left side of the rectum of a 20 mm. pig embryo (H.E.C.,1702), showing external surface. X 200, reduced 3/5.


Brain
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P.B.S.
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N.A.
O.M.
D.P.G.
D.S.L.G.
S.M.G.
Lr.
I.C.
M.C.S.
C.T.C.
Thr.G.
Oe.
Tr.
T.S.
Spinal
Cord
Heart
L.B.
Liver
Oe.
G.D.
C.D.
D.C.
G.B.
St.
Ao.
D.Pan.
V.Pan.
Y.S.
Cae.
Nc.
R.

Fig. 1

Fig. 2

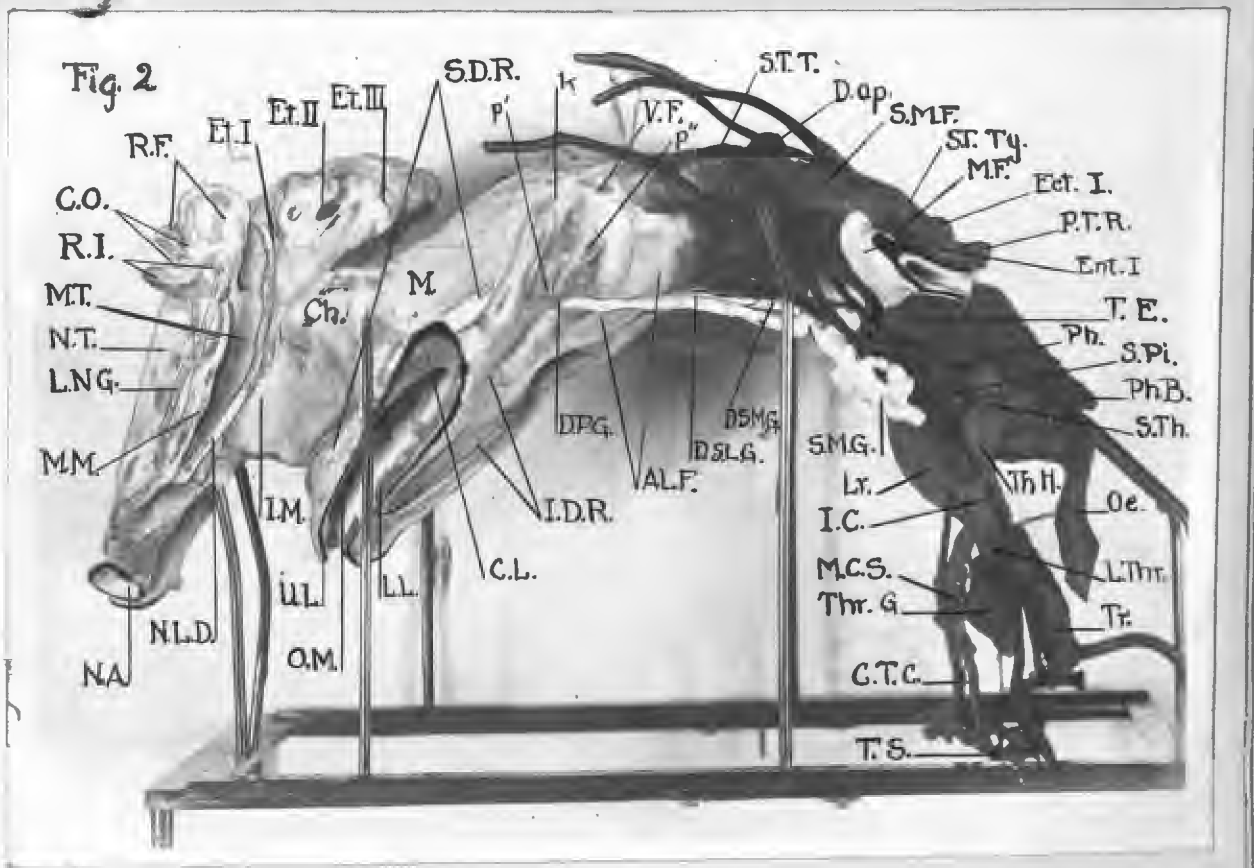

R.F.
C.O.
R.I.
M.T.
N.T.
L.N.G.
M.M.
N.A.
N.L.D.
I.M.
U.L.
O.M.
L.L.
Et.I
Et.II
Et.III
Ch.
M.
S.D.R.
C.L.
I.D.R.
P'
K
V.F.
P''
D.P.G.
A.L.F.
D.S.L.G.
D.S.M.G.
S.T.T.
D.op.
S.M.F.
S.T. Ty.
M.F.
Ect. I.
P.T.R.
Ent. I
T. E.
Ph.
S.Pi.
Ph.B.
S.Th.
S.M.G.
Lr.
Th.H.
I.C.
Oe.
M.C.S.
L.Thr.
Thr. G.
Tr.
C.T.C.
T.S.

Fig. 3

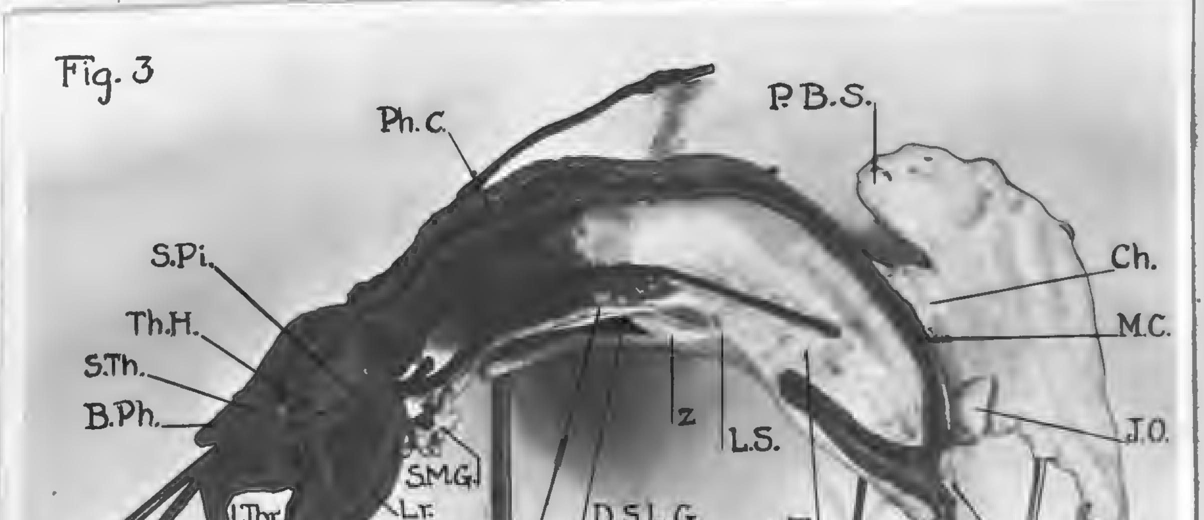

Ph. C.
P. B. S.
S.Pi.
Th.H.
S.Th.
B.Ph.
Ch.
M.C.
J.O.
z
L.S.
a.T.
S.M.G.
Lr.
I.C.
L.Thr.
Oe.
D.S.L.G.
D.S.M.G.
Thr.G.
M.C.S.
C.T.C.
Tr.
T.S.
S.D.R.


Fig. 4
C.O.
Et.I.
Et.II.
Et.III.
P.B.S.
P.B.S.
S.D.R.
S.D.R.
V.F.
C.L.
D.P.G.
D.P.G.
V.F.
X
X'
S.T.T.
D.ap.
S.M.F.
Ph.
S.T.Ty.
T.F.
Et.I
S.M.
Th.H.
P.T.R.
C.C.A.

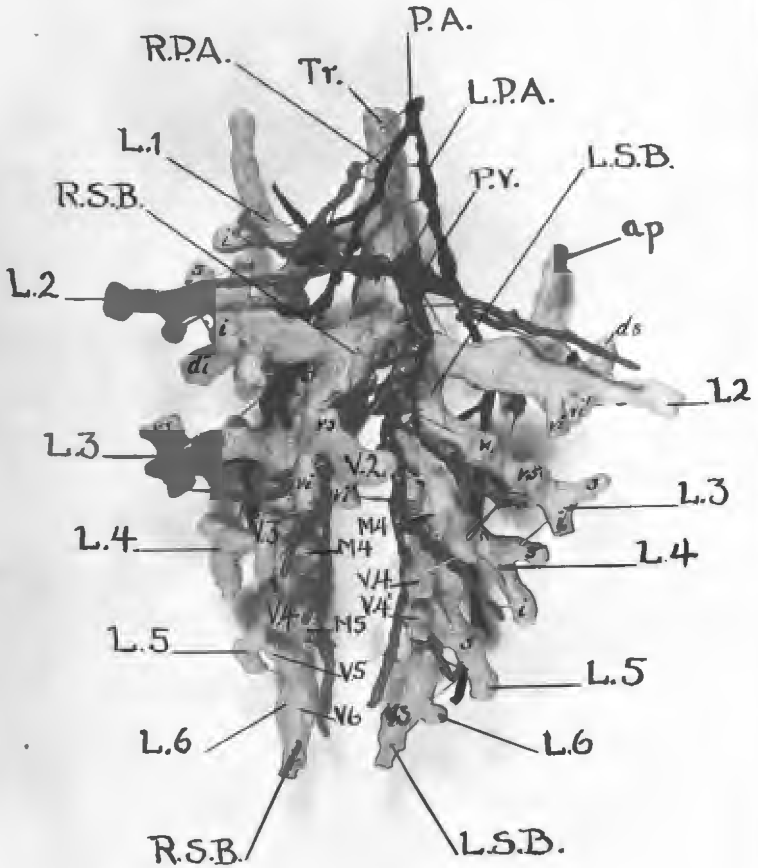

P.A.
R.P.A.
Tr.
L.P.A.
L.1
P.V.
L.S.B.
R.S.B.
ap
L.2
L.2
L.3
V.2
M4
L.3
L.4
V.3
M4
L.4
V.4
V.4
V.4
M5
L.5
V5
L.5
L.6
V6
L.6
R.S.B.
L.S.B.

Fig. 5.

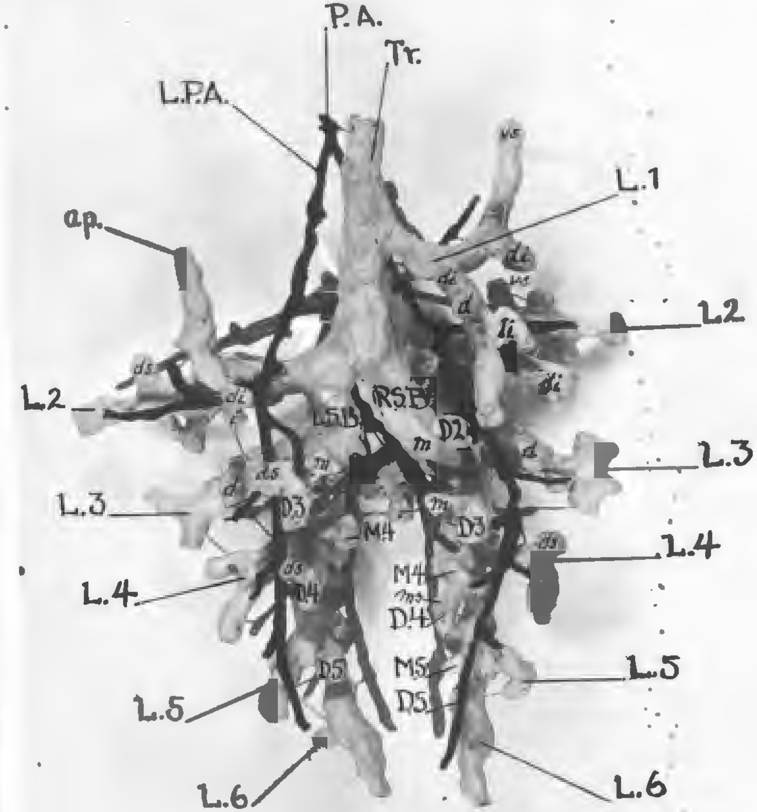

P.A.
Tr.
L.P.A.
L.1
ap.
L.2
L.2
R.S.B.
L.S.B.
D2
L.3
L.3
D3
M4
D3
L.4
L.4
D4
M4
D.4
L.5
D5
M5
D5
L.5
L.6
L.6

Fig. 6

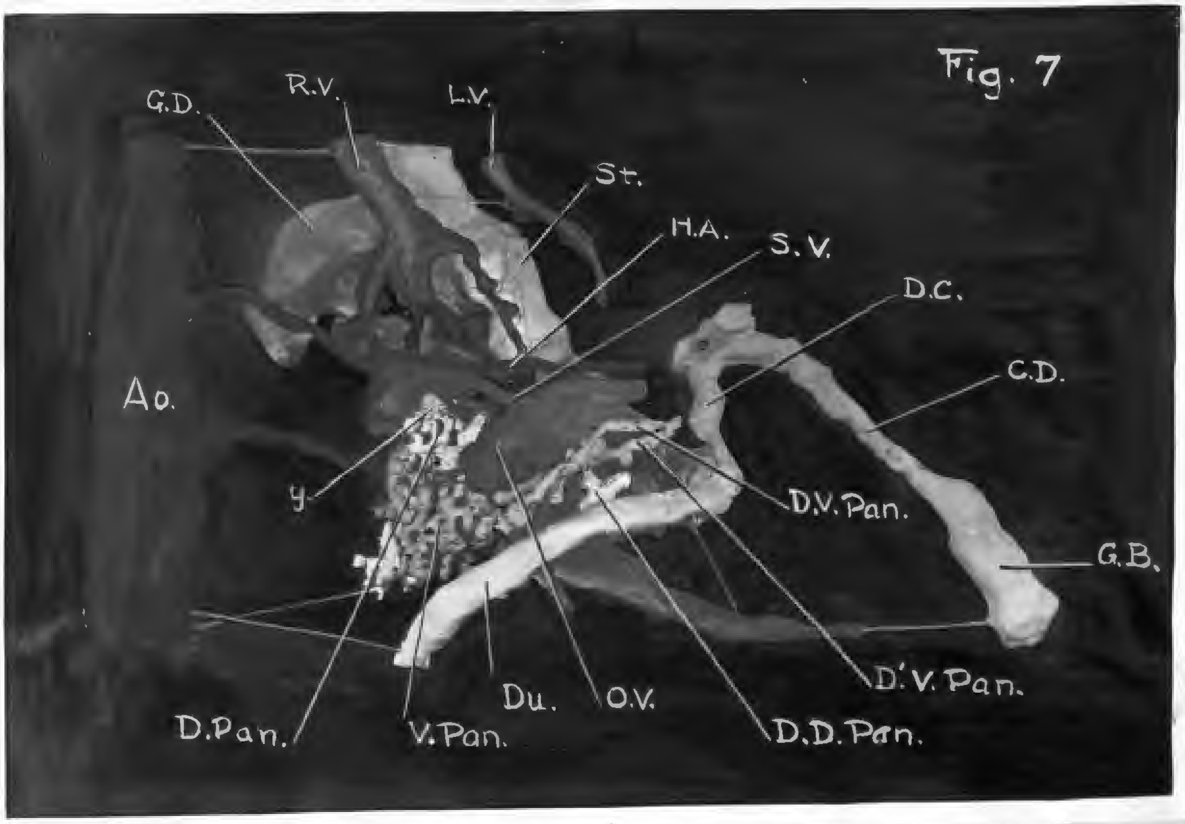


Fig. 7
G.D.
R.V.
L.V.
St.
H.A.
S.V.
D.C.
C.D.
Ao.
y
D.V. Pan.
G.B.
D'.V. Pan.
Du.
O.V.
D.Pan.
V.Pan.
D.D.Pan.

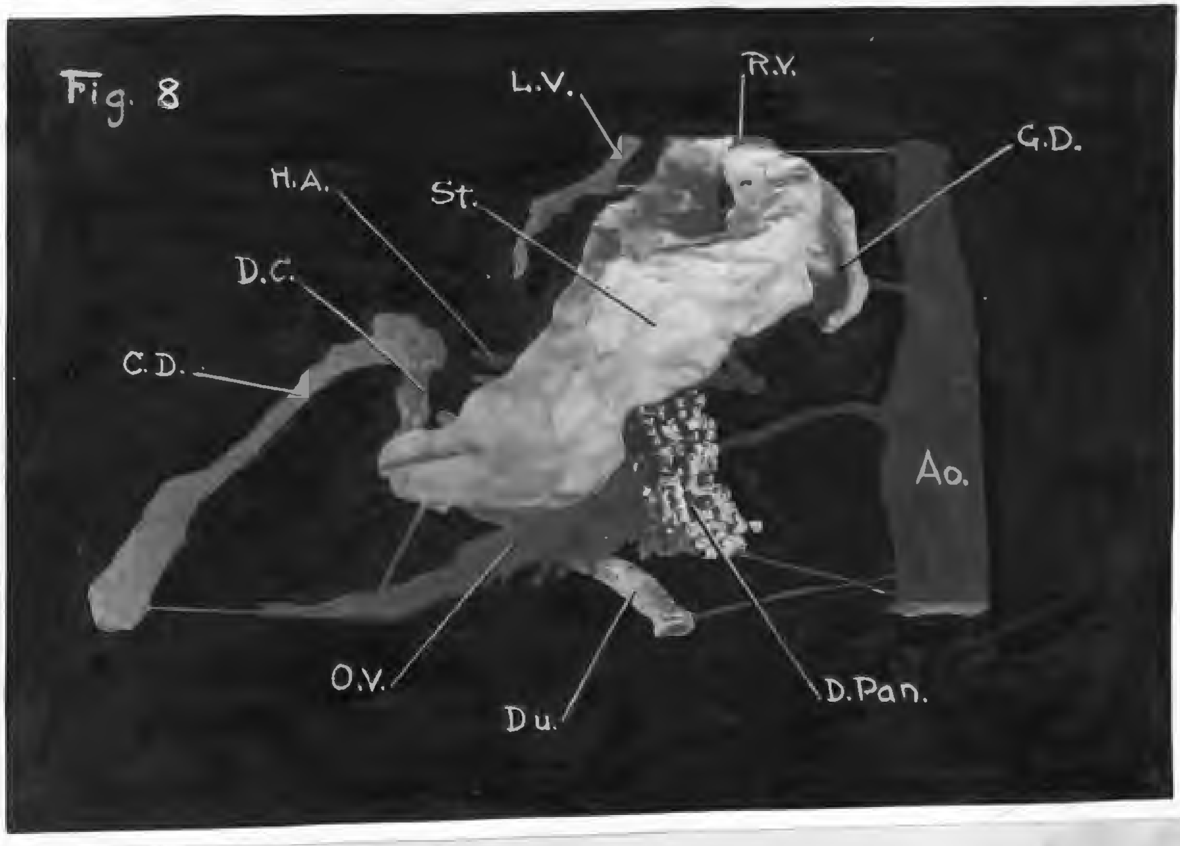


Fig. 8
L.V.
R.V.
G.D.
H.A.
St.
D.C.
C.D.
Ao.
O.V.
Du.
D.Pan.

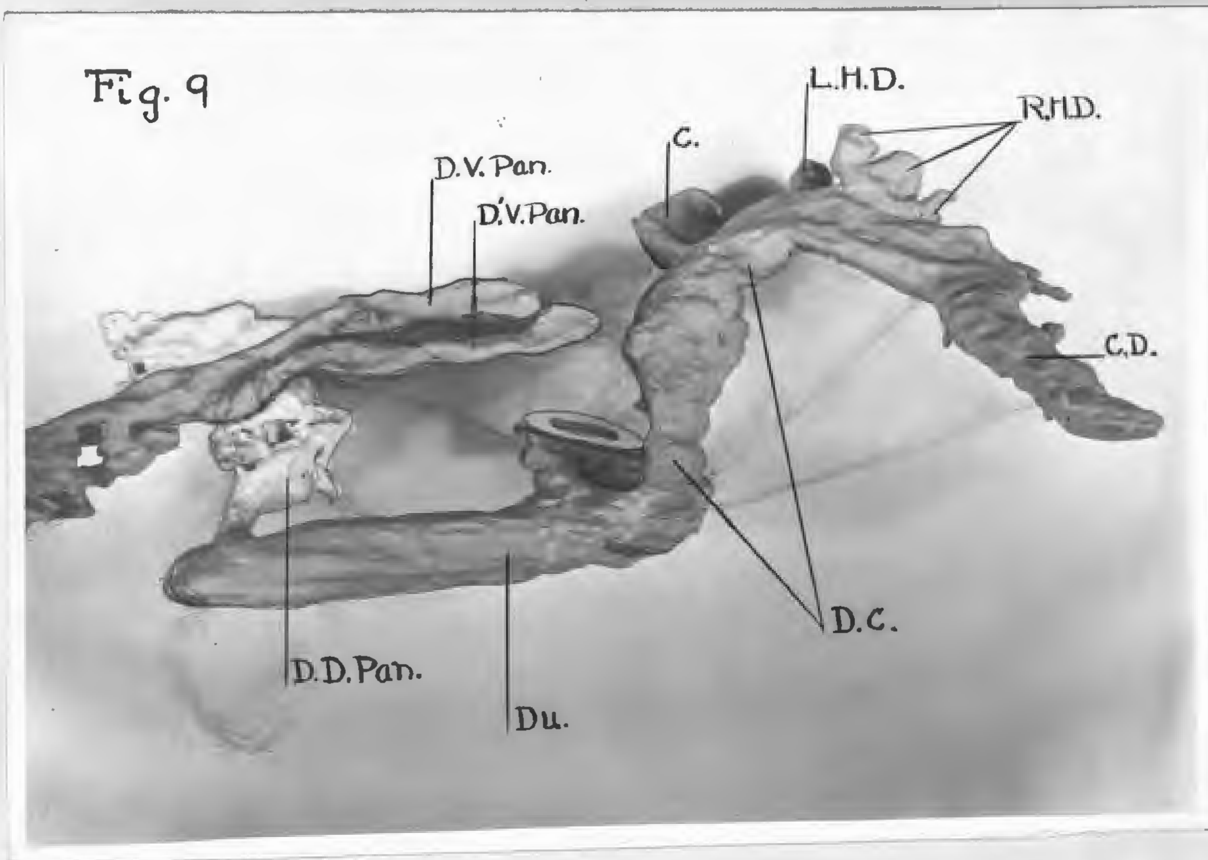
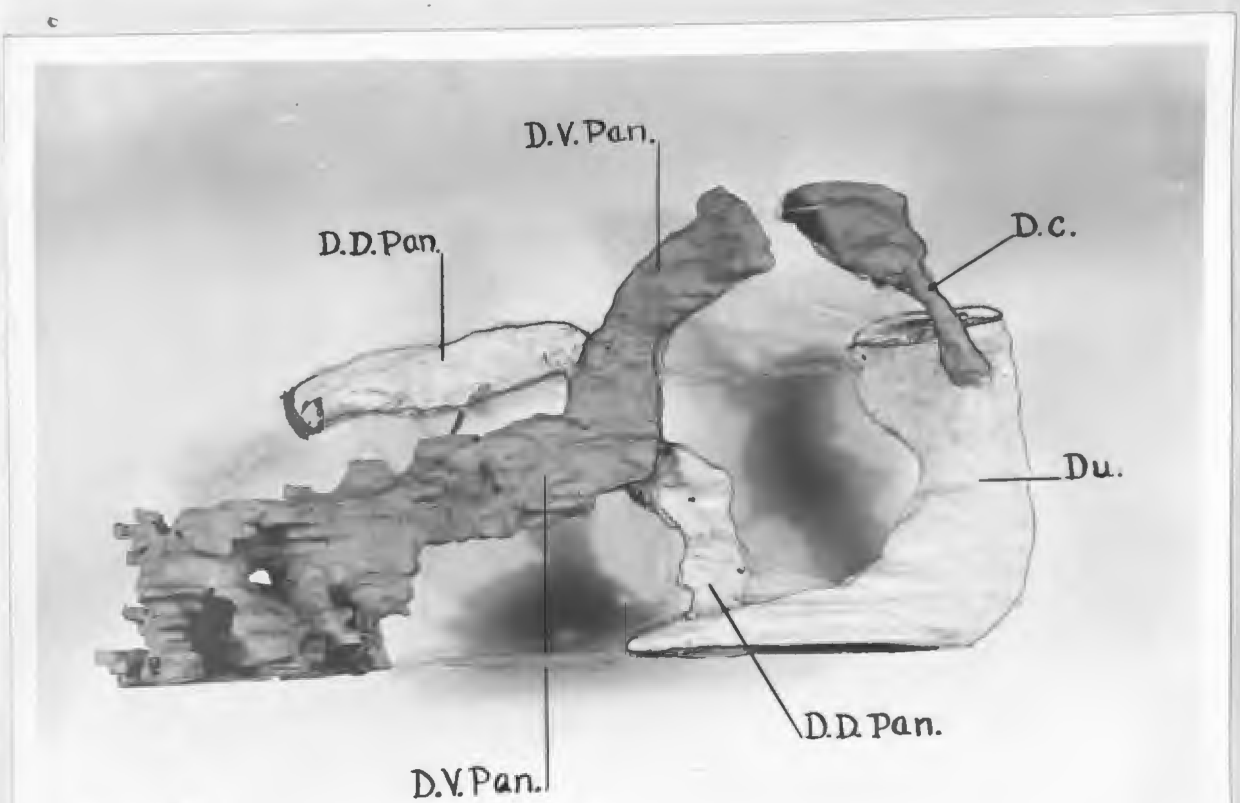


Fig. 9
L.H.D.
R.H.D.
C.
D.V. Pan.
D'V. Pan.
C.D.
D.C.
D.D. Pan.
Du.


D.V. Pan.
D.D. Pan.
D.C.
Du.
D.D. Pan.
D.V. Pan.
Fig. 10

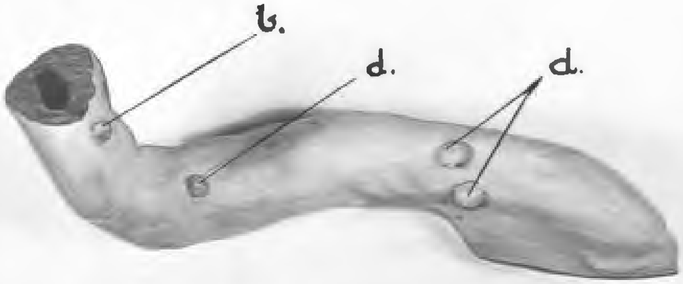



Fig. 11

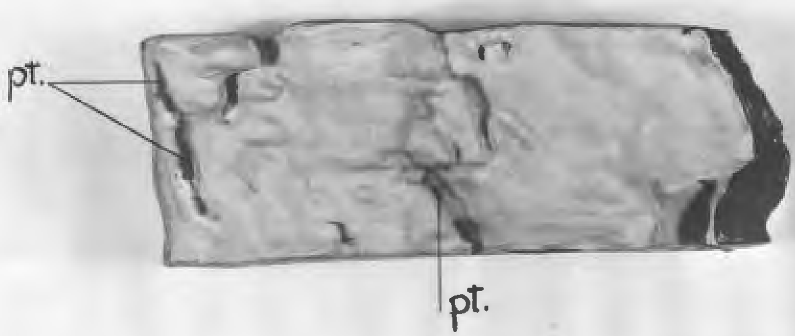



Fig. 12

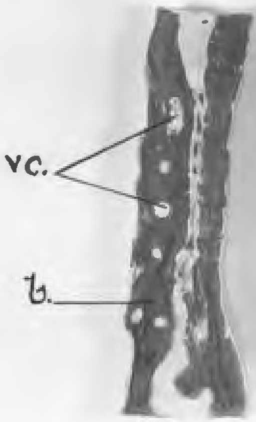



Fig. 13

Fig. 14

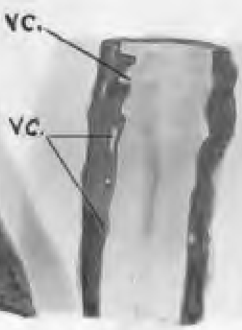



Fig. 15

Fig. 16

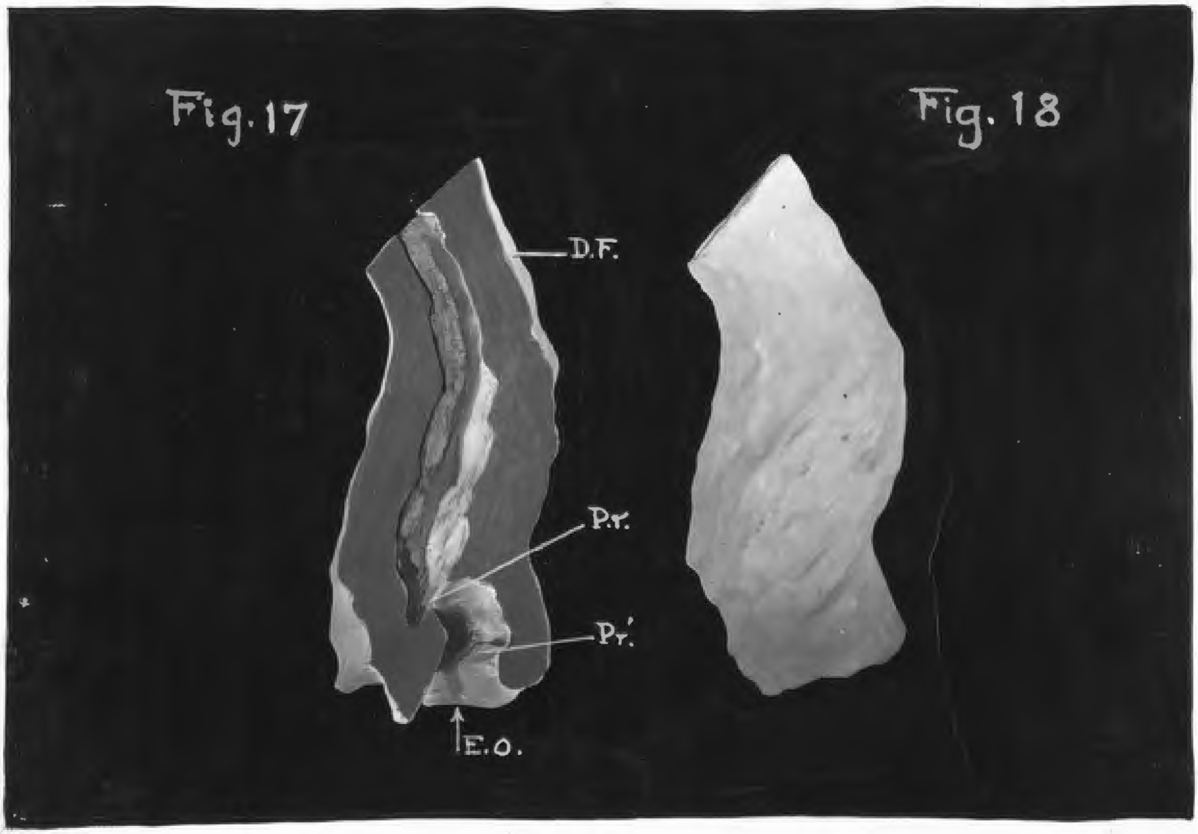


Fig. 17
D.F.
P.r.
P.r'.
E.O.
Fig. 18