THE ABDOMINAL DISTRIBUTION OF THE VAGUS

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IN the course of some work on the influence of the vagi nerves on the functions of the stomach, it was found necessary to obtain an accurate knowledge of their anatomical distribution in the abdomen, and this paper is the outcome of the investigation.

The course and distribution of the vagi nerves to the oesophagus and to the intra-abdominal organs are given in very general terms and brief space in the present-day text-books of anatomy. The literature reveals many varying statements as to the arrangement and manner of distribution of their branches in the sub-diaphragmatic region, whilst the structure of the oeso-phageal plexus as shown by earlier observers has been neglected. In any account of the sub-diaphragmatic distribution of the vagi, it is necessary to consider the influence of the structure of the oesophageal plexus on this distribution.

Perman summarises the differences found by various workers, the principal being:

1. The number of nerve stems passing through the oesophageal opening of the diaphragm.
2. The presence or absence of an anterior and posterior gastric plexus.
3. The presence or absence of a subserous gangliform plexus.

He himself, writing in 1916, denies the presence of any subserous ganglia and has never found either an anterior or a posterior gastric plexus.

The work of most interest and importance is found in the writings of Swan, Bourgery, Kollmann, Perman and Latarjet.

Swan (1834) gives an interesting account of the distribution of the vagi nerves, illustrated by very beautiful plates. He states that about the lower part of the oesophagus the vagi form the oesophageal plexus; from this two trunks are derived passing through the oesophageal opening of the diaphragm, one lying anteriorly and the other posteriorly. Three branches of the right vagus together with one from the left form the posterior trunk; the anterior trunk is formed by the union of two branches of the left vagus with one from the right. Further he describes a communication from the left to the right vagus about the level of the roots of the lungs.

The posterior trunk supplies filaments to the cardia, some of which com-municate with similar twigs from the anterior division; branches are then supplied to the posterior aspect of the stomach. A branch to the splenic plexus is noted; also communications with twigs of the anterior trunk on the

left gastric artery and with branches of the right hepatic plexus on the right gastric artery, these nerves being then distributed to the stomach. Communications with branches of the coeliac plexus about the left gastric artery are referred to. The nerve is described as terminating in the coeliac plexus. The anterior trunk supplies branches to the cardia, some of these communicating with twigs of the posterior trunk as noted above. Several branches pass to the left hepatic plexus. The main branches follow the lesser curvature of the stomach and are distributed to the anterior aspect of this organ; some run with the left gastric artery to meet on this artery branches of the right hepatic plexus as well as filaments from the posterior trunk.

The hepatic branches are figured as passing to the porta hepatis between the layers of the lesser omentum. The plates show an anterior gastric plexus.

Bourgery (1844) shows the anterior trunk divided into three stems and, as such, passing through the diaphragm: these are formed from several branches of the left vagus and one from the right. The posterior trunk, derived from three branches of the right vagus and four of the left, is broken up at the oesophageal opening into numerous divisions. A plexiform mass is figured. The stems of the posterior trunk are distributed to the posterior aspect of the stomach and to the coeliac ganglia. Communications between branches of the anterior and posterior trunks are to be seen on the lesser curvature, but no posterior gastric plexus is shown.

The stems of the anterior trunk give hepatic branches, a branch to the pyloric region, and branches to the anterior aspect of the stomach.

Communications with the sympathetic about the left gastric artery are shown. He names, but does not illustrate, an anterior gastric plexus.

Kollmann (1860) observed that both vagi form about the lower oesophagus the oesophageal plexus and that, near the oesophageal opening of the diaphragm, branches from this form two main stems, one lying anteriorly and one posteriorly; each stem contains fibres of both vagi. He noted that in the cat and rabbit the plexus maintains a constant relation and he describes the arrangement in the dog.

An anterior and a posterior gastric plexus are described. No plexuses are found in the rabbit, cat or dog, though some connections exist.

The anterior stem passes through the diaphragm in two or three branches, and forms on the cardia the anterior gastric plexus; this varies in size and may be absent. Branches pass to the liver through the lesser omentum, these and the main branches to the anterior surface of the stomach are described. Branches pass to the pylorus and form connections with the sympathetic fibres about the *left* gastric artery; together they supply this region.

The sympathetic nerves to the anterior surface of the stomach were examined in fifteen cases: in four, branches were found passing to the left of the oesophagus to reach the anterior stomach wall, these being derived from the left coeliac plexus or from the sympathetic plexus about the left inferior phrenic artery. In one case, Kollmann found communications between these fibres and vagal fibres, and in three cases branches passed through the lesser omentum to the liver without joining the vagal gastric branches. The posterior stem, having passed the diaphragm, gives about one-third of its fibres to the posterior aspect of the stomach; these communicate with sympathetic twigs to form the posterior gastric plexus, which, like the anterior, varies in size and may be absent.

Branches are only distributed over the proximal half of the posterior

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surface, the distal third receiving sympathetic fibres from the plexus about the left gastric artery. The remaining two-thirds of the stem pass to the coeliac plexus and through its connections to the liver, pancreas, spleen, kidneys, suprarenals and small intestine.

Perman (1916) gives an exhaustive review of the literature up to the time of his work, but does not refer to that of Swan. His own work is especially concerned with the distribution of the branches of the vagi to the stomach; these he describes in detail. He has never observed the presence of either an anterior or posterior gastric plexus as described by many others, although he notes some small communications on the lesser curvature between the branches of the anterior and posterior vagal trunks. He believes that the ganglia lying under the serosa and described by Openchowski, Worobjew and Muller, as well as others, are merely those of Auerbach's plexus appearing through defects in the longitudinal muscle coat.

Latarjet (1921) and his co-workers have of recent years investigated the distribution of the vagi to the stomach and liver. Their findings for dog and man are similar; the anterior trunk (left vagus) supplies four or five branches to the stomach, the main branch following the lesser curvature to reach and supply the pyloric antrum; the posterior trunk (right vagus) also gives off rami which run with sympathetic twigs to the porta hepatis. The pylorus is supplied from above by fine twigs (supra-pyloric nerves), which run a recurrent course in the lesser omentum and are derived from the nerves to the liver; the latter fibres are mainly if not entirely sympathetic. The posterior trunk sends a stem to the coeliac plexus. They point out that the "stomach reservoir" and the pylorus differ in the manner of their nerve supply. Plexus formation was not observed.

Sympathetic fibres reach the liver as described above and such fibres also reach the stomach; they follow the left gastric artery along the lesser curvature and anastomose with vagal twigs. Other sympathetic fibres run with the right gastro-epiploic artery and supply a few sparse twigs to the stomach along the greater curvature; they are derived from the nerves about the hepatic artery.

It will be seen from the literature that some of the earlier workers have described and figured the structure of the oesophageal plexus; of late years it is usual to find only brief references to a plexus about the lower third of the oesophagus. Swan figured and described the conformation of the plexus, and later Kollmann described it, emphasising that both vagi nerves supply fibres to both surfaces of the stomach. Duccheschi, quoted by Cannon, has observed that one cervical vagus can innervate the whole stomach. As regards the number of trunks passing through the oesophageal opening of the diaphragm, descriptions vary. Swan shows a single anterior and a single posterior stem; Bourgery figures multiple anterior branches, as do Henle and Spalteholz: Bourgery figures also multiple posterior: Kollmann states that the anterior trunk is divided into two or three branches whilst the posterior apparently remains single: Perman shows the anterior either single or divided into two, the posterior single. Again, the presence of an anterior and posterior gastric plexus is in doubt; amongst those describing these plexuses are Swan, Bourgery, Kollmann, Luschka, Henle, Schwalbe, Hollstein, Jonnesco and Spalteholz:

they have not been described by Sappey, Schafer and Symington in Quain's *Anatomy*, and Perman amongst others. The statement of Kollmann that they are variable in size and may be absent would appear to reconcile these observations, but Perman in 1916 could find neither plexus present in dissections of twenty specimens. Many workers in describing these plexuses, limit their formation to the gastric branches proper; some have described all branches as taking part in their formation.

The accounts of the distribution of the branches of the anterior trunk to the liver are not without conflicting statements; most authors agree that a branch or branches from the anterior trunk pass to the porta hepatis, crossing high up between the layers of the lesser omentum. Whether nerves pass along the lesser curvature and then proximally from the pyloric region is more doubtful; Valentine has described the latter twigs. Others state that the main vagal branches do not reach the distal portion of the stomach. It follows from the last statement that there exists a divergence of opinion as to the manner in which the pylorus is innervated. Kollmann describes branches of the anterior stem passing along the lesser curvature to the pylorus and thence proceeding to the first stage of the duodenum. Sappey also described these. Latarjet attributes the supply of the pylorus exclusively to the hepatic nerves derived from the coeliac plexus; Swan also figures such twigs.

It is to be noted that Kollmann, with Henle and Luschka, states that the posterior trunk only supplies the proximal part of the posterior surface of the stomach, the remainder receiving sympathetic twigs; the majority of workers however describe all this surface as receiving twigs from the posterior stem. The descriptions given of the abdominal distribution of the posterior trunk, other than to the stomach, are meagre. A full discussion of the literature is to be found in the article by Perman.

<div align="center">METHOD</div>

Specimens for dissection were prepared according to the method described by Perman, which is an elaboration of that of Woolridge.

1. The tissues are immersed in acetic acid 1 per cent. for 24 hours.
2. They are washed and placed in carbolic acid 6 per cent. for from 20 to 40 minutes.
3. They are again washed and then preserved in a saturated watery solution of picric acid; after 24 hours in this they are ready for dissection.

Prepared in this manner the specimens are soft and pliable and the nerves are easily recognised as white glistening strands. Specimens keep indefinitely in the picric acid solution, but it must be borne in mind that the penetrative action is not great and that the larger organs, such as the liver, may undergo central autolysis.

The terminology used follows the B.N.A., and as regards the parts of the stomach the description given in Cunningham's *Text-Book of Anatomy* is followed.

Dissections were made of six infants, aged three to nine months, and in one boy of fifteen years. The following account is compiled from these; minor individual variations occur and are referred to in the descriptions of the individual specimens.

DISSECTION OF THE VAGUS

Both vagi, having passed posterior to the lung roots, incline anteriorly and medially and proceed to divide, the right usually into three branches, sometimes four, the left almost invariably into three. These branches are
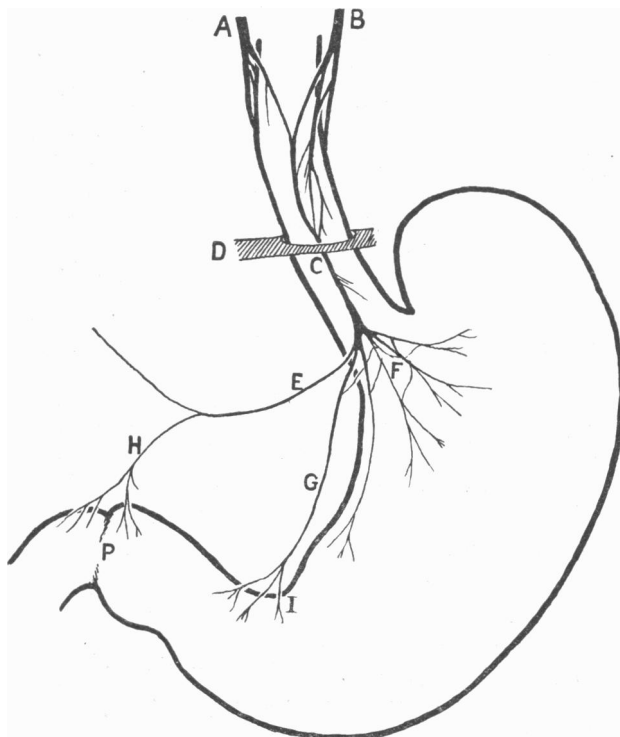

Fig. 1. Drawing made from a dissection showing the normal formation and distribution of the anterior vagal trunk. *A*, right vagus. *B*, left vagus. *C*, anterior vagal trunk. *E*, hepatic branch. *F*, gastric branches. *G*, principal anterior nerve of the lesser curvature. *H*, branches to pylorus and first stage of the duodenum. *P* indicates the position of the pylorus; *I*, that of the incisura angularis, and *D* the diaphragm.

then arranged about the lower third of the oesophagus in the following manner: two branches of the left nerve pass to the anterior aspect of the oesophagus and there unite with one branch of the right which has also reached this aspect; the latter branch is small as compared with the remaining divisions of the right nerve. Together these nerves form a very simple plexus on the anterior surface of the oesophagus, and from this one or two stems pass through the oesophageal opening of the diaphragm, forming the anterior vagal trunk.

The remaining divisions of the right and left nerves, in number usually two or three of the right and one of the left, have by now passed to the posterior aspect of the oesophagus and there form a plexus, again simple, from which there usually arises a single trunk, the posterior vagal trunk, passing through the oesophageal opening of the diaphragm.

The oesophagus is supplied by numerous fine twigs which arise from these various nerve stems as they lie closely applied to its wall. Intercommuni-
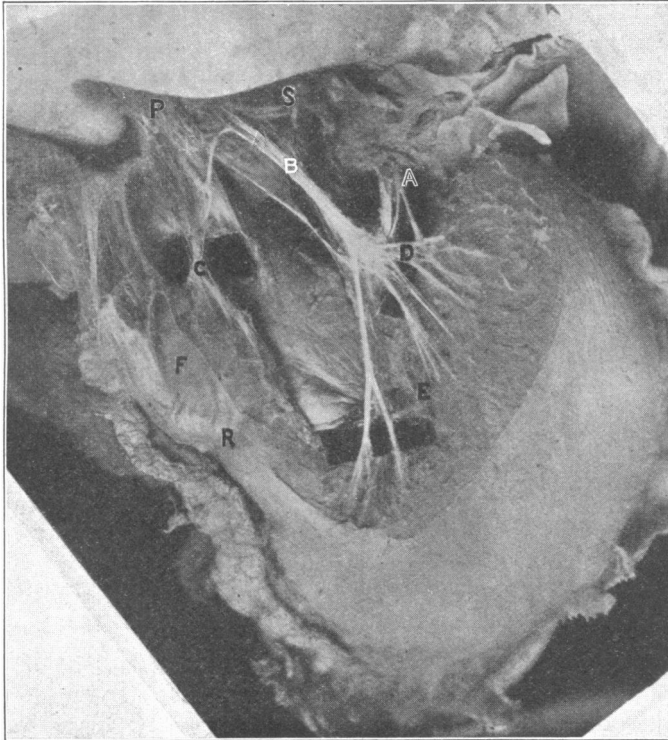

Fig. 1 A. Photograph of a dissection of the anterior vaga trunk and its branches in a child aged three months. *A*, anterior vagal trunk (two stems) on the lower oesophagus. *B*, hepatic branches. *C*, pyloric nerves (vagal and sympathetic). *D*, cardiac and gastric branches. *E*, principal anterior nerve of the lesser curvature. *P* indicates the porta hepatis; *S*, the caudate or Spigelian lobe of the liver; *F* is placed on the first stage of the duodenum, and *R* on the pylorus.

cations between the main stems of the anterior group are found and between the stems of the posterior group, varying in number, and with their number the plexus varies in complexity. The oesophageal plexus is therefore seen to be composed of an anterior and a posterior group of nerves.

The anterior vagal trunk (fig. 1), having passed through the oesophageal opening as one or two stems, supplies several fine twigs to the lower end of

the oesophagus and to the cardia; it then breaks up into its main branches, in most cases from three to six in number. These may be divided into two groups, a group lying to the right and on an anterior plane usually consisting of two stems, and a group to the left and on a deeper plane of three to four stems.

The left group may or may not show interconnections, few or many in number, in the latter case an anterior gastric plexus is formed. Its main branches of distribution associate themselves with the anterior branches of the left gastric artery, and supply the region of the anterior surface of the cardia, fundus and proximal portion of the body of the stomach. Some communications are also always present with the right group of branches. The right group gives origin to three main branches of distribution; the first passes out into the lesser omentum and proceeds towards the porta hepatis, its manner of termination being described below. The second, a large nerve, passes down between the layers of the lesser omentum, a short distance from, and parallel to, the lesser curvature of the stomach; it is distributed to the anterior surface of the pyloric antrum and body of the stomach in the neighbourhood of the incisura angularis, but does not reach the pyloric canal. The third branch lies on and follows the lesser curvature along the line of attachment of the lesser omentum; it is to be traced in most cases to the incisura angularis. These last two are, in most instances, reinforced by fibres from the left group of branches. Communications to the coeliac plexus from the branches of the anterior vagal trunk are present, passing proximally with the left gastric artery. One or two communications are received from branches of the posterior trunk on the lesser curvature in the region of the cardia. That branch of the right group proceeding towards the porta hepatis is frequently duplicated; its terminal twigs are divided into two series, a proximal which can be traced into the porta hepatis, and a distal turning downwards, from which twigs pass (a) to the pylorus and first stage of the duodenum, (b) to run with the right gastric artery, and thus to the region of the pyloric canal, (c) to run deep to the pylorus and first stage of the duodenum with the gastro-duodenal artery and so towards the head of the pancreas and second stage of the duodenum, (d) to run proximally on the wall of the hepatic artery, and (e) to communicate with sympathetic twigs passing to the gall-bladder. Those fibres running on the walls of the right gastric, gastro-duodenal and hepatic arteries soon become lost amongst sympathetic twigs, and in many cases they may be observed to communicate with these.

The posterior vagal trunk (fig. 2) in most cases a single stem, supplies fine twigs to the lower oesophagus and cardia, the lowest of which is of some size and constancy. It then divides shortly after passing through the oesophageal opening into two main divisions: of these the smaller is destined for the stomach, the larger for the coeliac and other abdominal sympathetic plexuses.

That portion for the stomach gives off first fine twigs to the lower oesophagus and cardia, one of which, distributed to the posterior aspect of the

cardia, is of some size and constancy. A branch then passes for a short and variable distance along the lesser curvature and sends twigs, in most cases two, to communicate with branches of the anterior vagal trunk. A common method of termination of the gastric stem is that in which a branch is given off to the posterior aspect of the proximal portion of the body; the stem then continues in the falciform ligament and gives off three branches for the supply of the posterior surface of the body and pyloric antrum, these at their terminations associating themselves with the branches of the left gastric artery. The
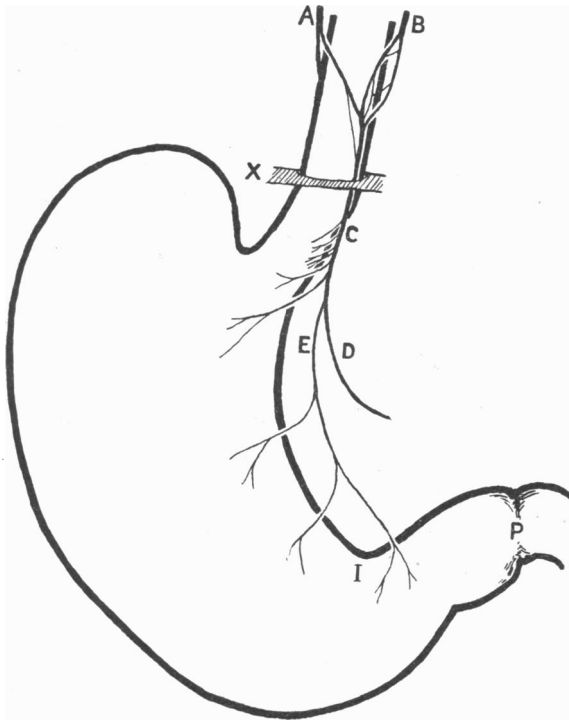
Fig. 2. Drawing made from a dissection illustrating the normal formation and distribution of the posterior vagal trunk. The stomach has been turned to the right, exposing the posterior surface. *A*, left vagus. *B*, right vagus. *C*, posterior vagal trunk. *D*, coeliac division. *E*, gastric division, which lies in the coronary falx. *P* indicates the position of the pylorus; *I*, that of the incisura angularis, and *X* the diaphragm.

most distal of them is distributed in the neighbourhood of the incisura angularis, but does not reach the pyloric canal.

As with the anterior vagal trunk a plexus, the posterior gastric plexus, may or may not be formed. When present, it is confined to the gastric divisions of the trunk. The major portion of the posterior vagal trunk associates itself with the stem of the left gastric artery and passes proximally. It supplies fibres to both right and left coeliac ganglia. Other fibres may be traced directly on to the splenic artery and to the pancreas and some, anastomosed with

sympathetic fibres, run with the superior mesenteric artery and hepatic artery and to the renal and suprarenal plexuses.
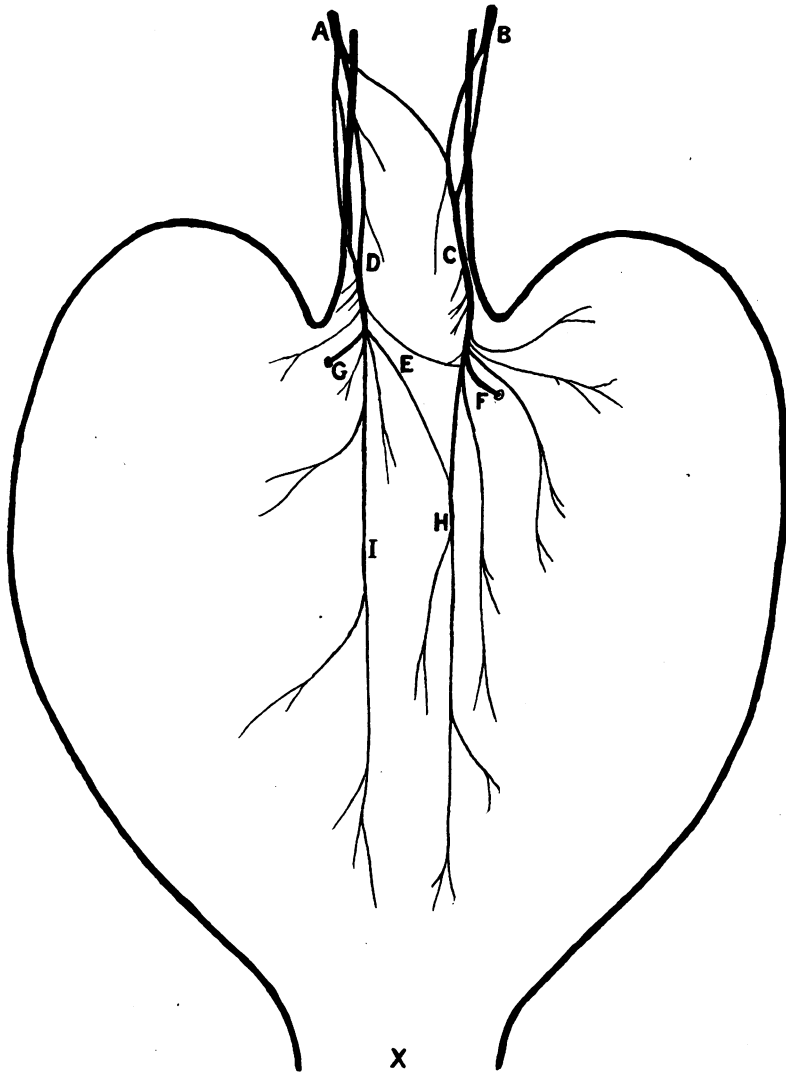

Fig. 3. Drawing made from a dissection to illustrate the distribution of the anterior and posterior vagal trunks. The stomach has been opened along the line of the greater curvature. *A*, right vagus. *B*, left vagus. *C*, anterior vagal trunk. *D*, posterior vagal trunk. *E*, communications on cardia between anterior and posterior vagal trunks. *F*, hepatic ramus. *G*, coeliac ramus. *H*, principal anterior nerve of the lesser curvature. *I*, principal posterior nerve of the lesser curvature. *X*, pylorus.

It is a matter of considerable difficulty to determine whether these last fibres are vagal or sympathetic or both, on account of their intricacy and of the manner in which the nerves are matted together.

A note on the origin and manner of distribution of the sympathetic fibres to the stomach is perhaps not out of place. This supply is entirely derived from the coeliac plexus.

These nerves are grouped as follows:

(a) Fibres from the coeliac plexus pass with the left inferior phrenic artery and so to the stomach; they wind about the anterior aspect of the lower extremity of the oesophagus from left to right, communicate with branches of the anterior vagal trunk and are distributed to the region of the cardia and fundus.

(b) Fibres pass with the left gastric artery from the coeliac plexus, and may be divided into three groups:—(1) Passing with the oesophageal and superior branches of this artery to the cardia and proximal part of the body of the stomach; reinforcements are received from the fibres with the right inferior phrenic artery. These twigs may be traced to the cardia and to communicate with branches of the anterior and posterior vagal trunks. (2) Fibres which pass with the main stem of the artery along the lesser curvature to supply both surfaces of the body of the stomach and pyloric antrum; one branch lying closely applied to the lesser curvature is of considerable size. (3) Fibres passing across between the layers of the lesser omentum towards the porta hepatis, communicating with the hepatic branches of the anterior vagal trunk in the majority of instances.

(c) Fibres pass from the coeliac plexus along the hepatic artery; these form several large nerves and are distributed with its branches; they reach the pyloric region of the stomach with the right gastric and right gastro-epiploic arteries.

Group (b) is much the most prominent and supplies the major portion of the stomach.

DISSECTION I. Female infant, aged 3½ months.

The oesophageal plexus: the left vagus divides into three main branches, the right into four. Two of those from the left nerve unite together with the smallest of the right to form the anterior vagal trunk, which passes through the oesophageal opening as a single trunk. The remaining branch of the left joins together with three of the right to form the posterior vagal trunk, passing through the oesophageal opening as a single stem. All these branches supply fine twigs to the oesophagus.

The anterior vagal trunk, having passed through the diaphragm, supplies numerous fine twigs to the lower oesophagus and cardia. It then divides into (1) a single hepatic ramus, passing out between the layers of the lesser omentum to the porta hepatis, and (2) four larger branches which pass to supply the stomach, no anterior gastric plexus being formed; the hepatic ramus was not followed further. The largest of the gastric branches lies in the lesser omentum and follows the lesser curvature as far as the region of the pyloric antrum; it is reinforced in the neighbourhood of the cardia by a small branch from the posterior vagal trunk.

The posterior vagal trunk divides into two portions, the larger passing towards the coeliac plexus along the trunk of the left gastric artery, the smaller to the stomach.

The latter branch supplies fine twigs to the lower oesophagus and cardia and also two small twigs which wind about the cardia to join branches of the anterior vagal trunk. Two main branches of the gastric division are then found passing along the lesser curvature deep to the plane of attachment of the lesser omentum; the proximal supplies the proximal portion of the posterior surface of the body of the stomach, whilst two to three branches

from the more distal supply the remainder of the posterior surface of the body and pyloric antrum.

No posterior gastric plexus is present.

DISSECTION II. Female infant, 6 months.

The oesophageal plexus: the left vagus divides into three branches, two of these unite together with one smaller branch of the right vagus on the anterior aspect of the oesophagus to form the anterior vagal trunk; this passes through the oesophageal opening of the diaphragm as a single stem. The right divides into three main branches: the smallest (as seen above) unites with the branches of the left vagus to form the anterior trunk, the remaining two together with the third branch of the left vagus, noted above, unite to form the posterior vagal trunk on the posterior surface of the oesophagus; this again passes through the oesophageal opening as a single trunk. All branches supply fine twigs to the oesophagus. Minor divisions of these branches exist accentuating the plexiform arrangement. The anterior vagal trunk, having supplied several small twigs to the oesophagus and cardia, breaks up on the anterior aspect of the cardia into at first three and later five main branches.

The two lying to the left and on a deeper plane form the anterior gastric plexus lying on the cardia and supplying branches to the cardia, fundus and body of the stomach; a branch passes in the lesser omentum along the lesser curvature of the stomach to the region of the incisura angularis. The two lying to the right and on a more superficial plane are distributed as follows: one follows the lesser curvature to the pyloric antrum; the other passes out between the layers of the lesser omentum to the liver, this branch communicates with the sympathetic fibres from the coeliac plexus which run with the right inferior phrenic and left gastric arteries. A branch from the deep division of the anterior vagal trunk also passes in the lesser omentum to the liver and is reinforced by a twig from the posterior vagal trunk. A third hepatic twig crossing in the lesser omentum is derived from the sympathetic plexus about the left gastric artery. From these branches which pass between the layers of the lesser omentum towards the liver, twigs may be traced into the porta hepatis, to the pylorus, and to unite with sympathetic fibres passing to the gall bladder; others run downwards posterior to the pylorus to pass with the gastro-duodenal artery towards the head of the pancreas and second stage of the duodenum, while yet others accompany the hepatic artery, passing proximally towards the coeliac plexus.

The posterior vagal trunk divides into two groups of branches, the smaller for the stomach, the larger for the coeliac and other sympathetic plexuses.

The branches for the stomach consist of several small oesophageal and cardiac branches, one of which is of some size. The remaining stem runs in the left gastro-pancreatic fold and gives off three branches for the supply of the posterior surface of the stomach and pyloric antrum; the most distal of these is distributed in the neighbourhood of the incisura angularis, but does not reach the pyloric canal.

No posterior gastric plexus is present.

The larger division of the posterior vagal trunk associates itself with the stem of the left gastric artery; two chief branches were identified entering the coeliac ganglia to the right and the left of the aorta. Twigs continued directly on to the splenic artery and into the substance of the pancreas, those on the splenic artery being finally lost amongst sympathetic fibres.

DISSECTION III. Female infant, 5 months (fig. 4).

Oesophageal plexus: the left vagus divides into three main branches, the right also into three, of which one is smaller than the remaining two. The last, together with two branches of the left nerve forms the anterior vagal trunk which passes through the diaphragm in the form of two stems lying close together. The posterior vagal trunk, a single stem, is formed by the union of one branch of the left vagus with two larger divisions of the right. All stems supply fine twigs to the oesophagus and this structural arrangement is complicated by smaller connections between the stems forming each trunk.

The two stems composing the anterior vagal trunk, having supplied twigs to the lower oesophagus and to the cardia, divide up on the anterior aspect of the cardia; the branches may be separated into two divisions, a right and a left. The left division supplies twigs to the fundus and proximal portion of the body and sends communications to the right group. The right division supplies four chief branches, the first passing out between the layers of the lesser omentum towards the liver; the second follows the lesser curvature lying in the lesser omentum, receives a communication from the left division and gives off, near its

origin, a branch which passes out in the lesser omentum and supplies the pylorus from above (fig. 4); it then terminates just proximal to the incisura angularis. Of the remaining two branches, one passes almost transversely to the left, being distributed to the proximal part of the body, the other lies deep and follows the lesser curvature; it may be traced almost to the incisura angularis.

An anterior gastric plexus is present, mainly formed by the branches of the left division. A deep branch passes back from the right division towards the coeliac plexus, along the trunk of the left gastric artery. Two communicating branches from the posterior vagal trunk are received in the region of the cardia.

The branch to the liver divides in the neighbourhood of the porta hepatis into two, the superior enters the liver, the inferior passes downwards and supplies twigs to the pylorus and first stage of the duodenum, while others run with the right gastric and hepatic arteries.

The posterior vagal trunk supplies fine twigs to the lower oesophagus and cardia, the lowest of which is a branch of some size; it then divides into two main divisions, a smaller gastric and a larger one which passes to the coeliac and other abdominal plexuses.

The gastric division gives off three principal branches; firstly one which passes along the lesser curvature for a short distance and anastomoses with branches of the anterior vagal trunk; secondly one which passes to supply the proximal part of the posterior surface of the stomach; the third branch divides into three twigs which reach the remainder of the posterior surface of the body, and the lowest of which reaches the incisura angularis and terminates on the posterior aspect of the pyloric antrum. These branches associate themselves with the posterior branches of the left gastric artery.

All these nerves are at their origins interconnected by an extremely fine and complex network of nerves, the posterior gastric plexus. The major division passes along the trunk of the left gastric artery to the coeliac ganglia in which it mainly terminates; other fibres however accompany the splenic artery.

Dissection IV. Male infant, 5 months.

Oesophageal plexus: the left vagus divides into three branches, the right into four. These are arranged in the usual manner; two from the left nerve and one from the right form the anterior vagal trunk; three of the right and one of the left the posterior vagal trunk. The anterior trunk passes through the oesophageal opening of the diaphragm as a single stem, the posterior trunk in the form óf two stems.

The anterior vagal trunk supplies fine twigs to the oesophagus and cardia and three branches to the fundus and proximal part of the body of the stomach; one branch follows the lesser curvature lying in the lesser omentum, supplies twigs to the body and terminates in the region of the incisura angularis, its terminal twigs reaching the pyloric antrum. An hepatic ramus is given off in the usual manner; this breaks up as it lies between the layers of the lesser omentum and becomes intermingled with sympathetic fibres. It gives off twigs to the porta hepatis and others which descend to the pylorus and first stage of the duodenum, whilst yet others run with the right gastric artery and with the hepatic artery. No anterior gastric plexus is present.

The posterior vagal trunk supplies the lower oesophagus and cardia as in other specimens and sends, on the cardia, communicating twigs to the branches of the anterior trunk, in particular its hepatic ramus. Its two stems then divide into gastric and coeliac divisions, the two gastric unite and proceed as a single stem in the left gastro-pancreatic fold; this stem supplies three branches to the posterior surface of the stomach and terminates near the incisura angularis: it reaches the pyloric antrum. Before union of the gastric divisions, that of the left side supplies one branch to the proximal portion of the body and to the fundus. The coeliac divisions pass separately to become lost in the coeliac plexus. No posterior gastric plexus is present.

Dissection V. Male, aged 15 years (figs. 5, 6 and 7).

The oesophageal plexus possesses the customary basic structure; two branches of the left vagus together with one of the right form the anterior vagal trunk: two branches of the left nerve and two of the right form the posterior vagal trunk. Both vagal trunks pass as single nerves through the oesophageal opening of the diaphragm. The anterior vagal trunk breaks up on the anterior aspect of the cardia into four branches, the three lying to the left supply the anterior aspect of the cardia, fundus and body, that on the right gives
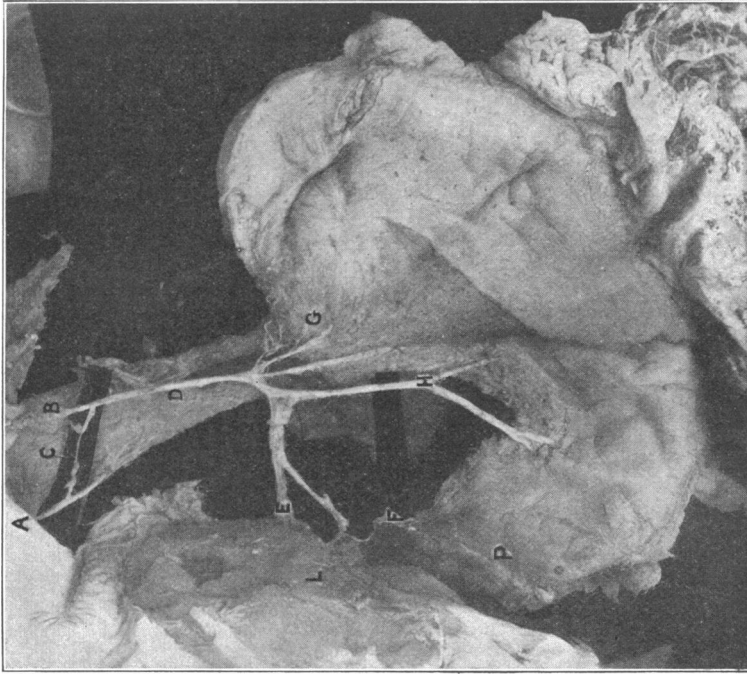
Fig. 5. Photograph of Dissection V, anterior aspect, illustrating the formation and distribution of the anterior vagal trunk. A, right vagus. B, left vagus (anterior branches). C, communication from right to left vagus. D, anterior vagal trunk. E, hepatic branches. F, descending branch to pylorus and first stage of the duodenum. G, gastric branches. H, principal anterior nerve of the lesser curvature. L is placed on the cut surface of the liver, the left lobe of which has been removed. P indicates the position of the pylorus.
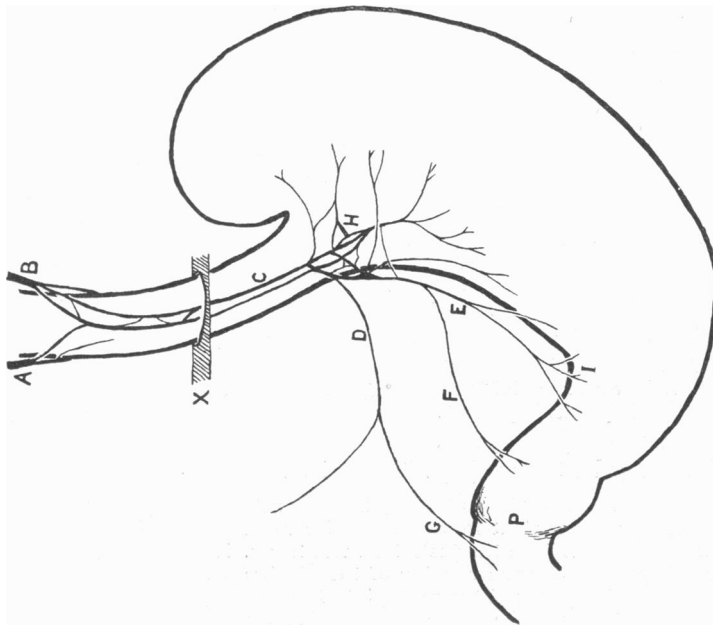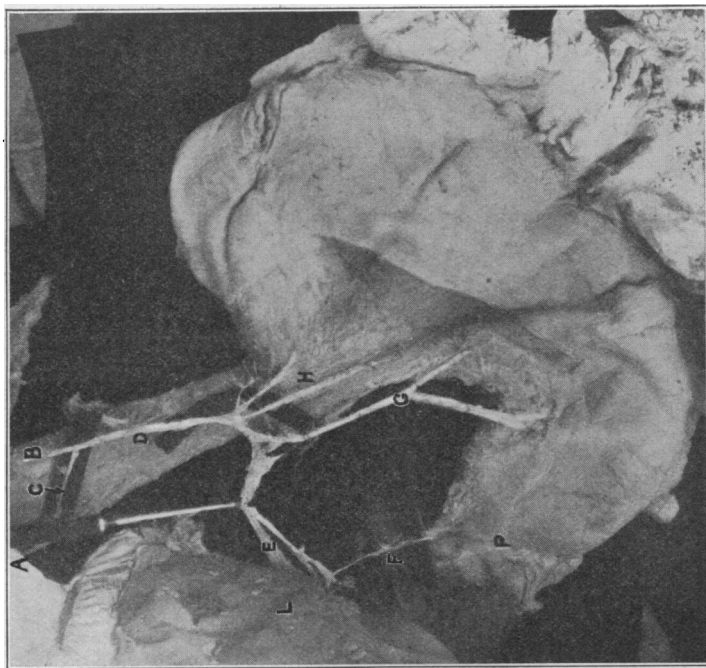

Fig. 4. Drawing made from Dissection III showing the vagal branch destined solely for the pylorus. A, right vagus. B, left vagus. C, anterior vagal trunk. D, hepatic branch. E, principal anterior nerve of the lesser curvature. F, branch to pylorus. G, branch to duodenum. H, gastric branches. P indicates the position of the pylorus; I, that of the incisura angularis, and X the diaphragm.
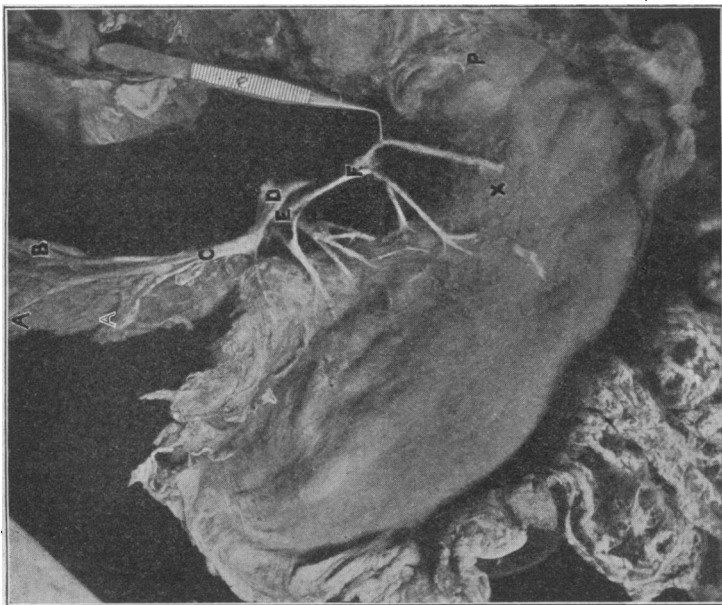
Fig. 7. Photograph of Dissection V, posterior aspect, illustrating the formation and distribution of the posterior vagal trunk. A, branches of left vagus. B, branches of right vagus. C, posterior vagal trunk. D, coeliac division. E, gastric division. F, principal posterior nerve of the lesser curvature. P indicates the position of the pylorus, and X the site of the incisura angularis.

Fig. 6. Photograph of Dissection V, anterior aspect, illustrating the formation and distribution of the anterior vagal trunk. A, right vagus. B, left vagus (anterior branches). C, communication right to left vagus. D, anterior vagal trunk. E, hepatic branches. F, descending branch to pylorus and first stage of the duodenum. G, principal anterior nerve of the lesser curvature. H, gastric branches. L is placed on the cut surface of the liver, the left lobe of which has been removed; P indicates the position of the pylorus.

origin to firstly, a large branch which lies in the lesser omentum and follows the lesser curvature, to be distributed in the neighbourhood of the incisura angularis; and secondly, branches to the liver, three in number, which form a plexiform arrangement in the lesser omentum. Pyloric twigs are derived from the lowest of these branches to the liver. The posterior vagal trunk supplies twigs in the normal manner to the lower oesophagus and to the cardia, the lowest of which is a branch of some size; the main trunk then divides into gastric and coeliac divisions. The gastric division runs in the left gastro-pancreatic fold and its continuation, the falciform ligament: it gives off two branches for the supply of the posterior surface of the body of the stomach and terminates in the region of the incisura angularis, some twigs reaching the pyloric antrum. The coeliac division passes mainly to the coeliac plexus; some twigs however pass onward together with sympathetic fibres. These were not followed further because of the intimate connections existing between them and the sympathetic fibres.

No anterior or posterior gastric plexus was present.

The remaining dissections differed in no essential detail from those described above.

The literature on the anatomy of the vagus in animals is scanty. The vagus of the rabbit, in particular the oesophageal plexus, is referred to by Kollmann. Krause briefly states that the left vagus supplies the anterior, the right the posterior surface of the stomach. Jacobi describes and figures with its variations the communications found between the two vagi nerves on the posterior surface of the oesophagus immediately proximal to the cardia: he mentions no other communications between the two nerves. In eight of ten dissections he found that the left vagus was mainly distributed to the small intestine; on stimulation, however, he found that in 17 out of 37 cases the left vagus acted mainly on the intestine, in 15 on the stomach and in 5 the action was approximately equal.

In the case of the cat Mivart states that the left vagus supplies the liver and ventral surface of the stomach, whilst the right supplies the dorsal surface and spleen. In addition to the note by this author, the only other reference I have found is a brief note by Kollmann on the oesophageal plexus.

The literature on the vagus of the dog is more extensive. Kollmann describes the structure of the oesophageal plexus and gives the branches of distribution: Ellenberger and Baum figure and describe the oesophageal plexus; they show the anterior trunk giving off hepatic rami as in man, whilst its terminal branches reach the pylorus: the posterior trunk is seen to terminate in the coeliac plexus. Latarjet states that the vagi are distributed in the dog as in man, the pylorus receiving its sole supply from the hepatic nerves.

Hartung has investigated the vagi of the sheep in their lower thoracic and abdominal course; he carefully describes the gastric and hepatic branches.

DISSECTIONS

The specimens were prepared for dissection in the same manner as described above for the human dissections. Twenty rabbits were dissected, twelve cats and six dogs. A description of the findings follows.

RABBIT (fig. 8).

The right and left vagi, having given off their pulmonary branches, communicate with one another ventral to the oesophagus. This communication, which occurs immediately

below the level of the roots of the lungs, usually takes one of two forms, but minor variations occur. The two main types are as follows:

(a) The more usual condition: a branch or branches of the right vagus pass to join the left nerve.

(b) Chiasma formation: the two nerve trunks unite into one for a short distance, then this divides again into two. Two trunks proceed distally from this plexus, both supplying twigs to the oesophagus, and having numerous intercommunications with one another. That on the right side soon passes dorsal to the oesophagus; that on the left passes down
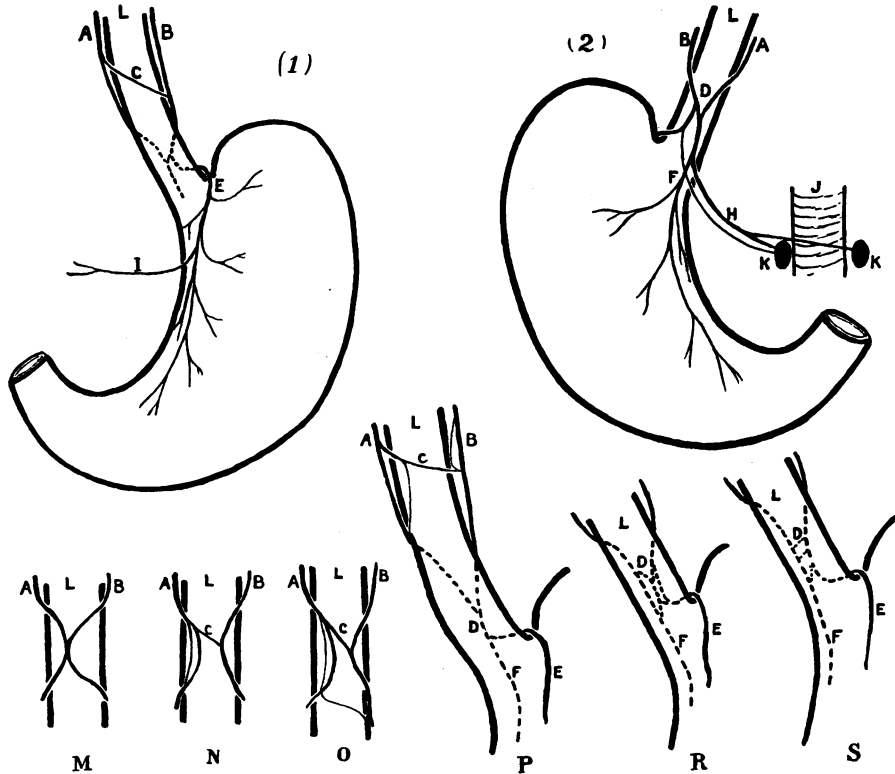

Fig. 8. Drawings illustrating the oesophageal plexus of the rabbit and the distribution of its branches, (1) anterior, (2) posterior. *A*, right vagus. *B*, left vagus. *C*, anterior communication between right and left vagi. *D*, posterior communications (supra-cardiac) between right and left vagi. *E*, anterior gastric vagus. *F*, posterior gastric vagus. *H*, coeliac division. *I*, hepatic branch. *J*, aorta. *K*, coeliac ganglia. *L*, oesophagus. *M, N, O* and *P* illustrate variations in the form of the anterior communication between the right and left vagi. *P, R* and *S* illustrate variations in the posterior (supra-cardiac) communications.

on the left of the oesophagus until, a short distance above the cardia, it also passes dorsally. Both trunks now unite on the dorsal aspect of the oesophagus immediately above the cardia; the manner and degree of union being most variable, ranging from a chiasma formation to that of two parallel trunks connected to one another by numerous delicate twigs. The most usual structure found is that in which one or two large twigs pass from the left to the right trunk, with in addition fine transverse communications. This formation together with two variants is figured above.

From this plexiform structure two main groups of branches arise, a right and a left. The left passes to the left and ventrally, winding about the lower extremity of the oesophagus to be distributed to the ventral surface of the stomach; the main branches run

along the lesser curvature and terminate in the pyloric antrum. One or more fine twigs arise proximally and pass out into the lesser omentum towards the liver. The right group passes dorsally and to the right supplying the dorsal surface of the stomach, while its main branches follow the lesser curvature to the pyloric antrum; in addition from this group there arise one or more nerves passing to the coeliac plexus. Both groups supply twigs to the cardia. The left group is also connected to the coeliac plexus either by a separate twig or by one combining with that of the right. The nerves do not form a plexus on the stomach wall.

CAT (fig. 9).

The connections and distribution of the vagi are more constant in the cat. Immediately below the level of the root of the lung both vagi nerves divide into two. The ventral branches of the right and left nerves unite together and proceed downwards as a single trunk upon the ventral aspect of the oesophagus; the branch from the right nerve is small.

This trunk supplies twigs to the oesophagus and ventral aspect of the stomach, and its chief branches are found along the lesser curvature; one branch, running in the lesser omentum close to the lesser curvature, is distributed to the pyloric antrum, and this nerve gives off hepatic twigs.
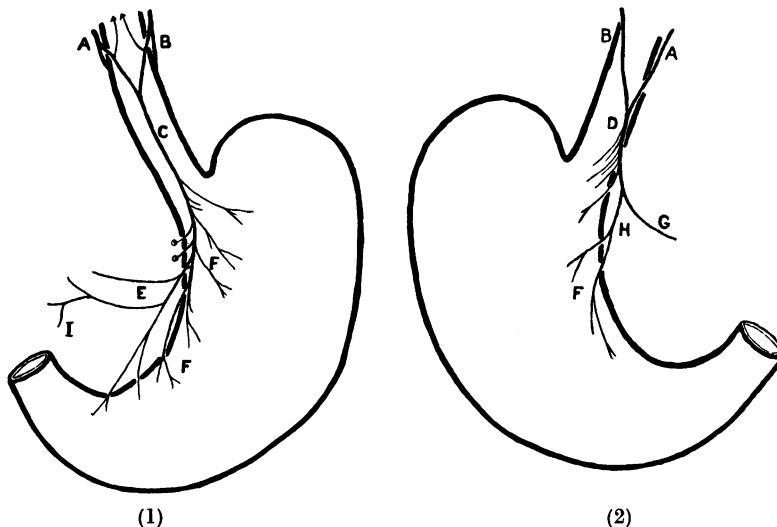

(1) (2)

Fig. 9. Drawings illustrating the formation and distribution of the anterior (ventral) and posterior (dorsal) vagal trunks in the cat. The anatomical arrangement in the dog is similar, (1) anterior, (2) posterior. A, right vagus. B, left vagus. C, anterior vagal trunk. D, posterior vagal trunk. E, hepatic branch. F, gastric branches. G, coeliac division. H, gastric division. I, pyloric branch.

The dorsal branches of the right and left nerves incline dorsally, supply twigs to the oesophagus and, at a point one to two centimetres proximal to the cardia, unite to form a single stem on the dorsal aspect of the oesophagus. This dorsal trunk is distributed to the dorsal surface of the stomach and to certain sympathetic plexuses and abdominal organs. The main branches of the gastric division are again found on the lesser curvature; they reach the stomach through the left gastro-pancreatic fold, one branch reaching the pyloric antrum. The second division arises about the level of the cardia and passes mainly to the coeliac plexus; twigs may however be traced directly accompanying the splenic, superior mesenteric and hepatic arteries, while others join the renal plexuses. The ventral trunk gives off proximally two or more fine twigs passing out into the lesser omentum towards the porta hepatis.

The nerves do not form a plexus on the stomach wall.

Dog.

A close resemblance is found to the cat. The vagi nerves divide to form ventral and dorsal trunks in a similar manner and position to that described above; the ventral branch of the right vagus is, as in the cat, considerably smaller than that of the left. The ventral trunk supplies the ventral surface of the stomach, sending its main branches along the lesser curvature between the layers of the lesser omentum; they may be traced to within 2 cm. of the pylorus. This trunk also gives off hepatic twigs, one or two in number; they pass high up in the lesser omentum to the liver and fine twigs from these pass downwards towards the pylorus. The dorsal trunk, as in the cat, divides into two; the gastric portion reaches the stomach through the left gastro-pancreatic fold and passes to within a short distance of the pylorus; its main branches lie along the lesser curvature. The second division gives off branches which may be traced to the coeliac plexus; others run with the superior mesenteric artery and splenic artery: the latter supply fine twigs which enter the pancreas.

Experiments were carried out in order to determine histologically whether fibres from each vagus nerve were distributed to both the anterior and posterior surfaces of the stomach, a mode of distribution strongly suggested by the macroscopic findings.
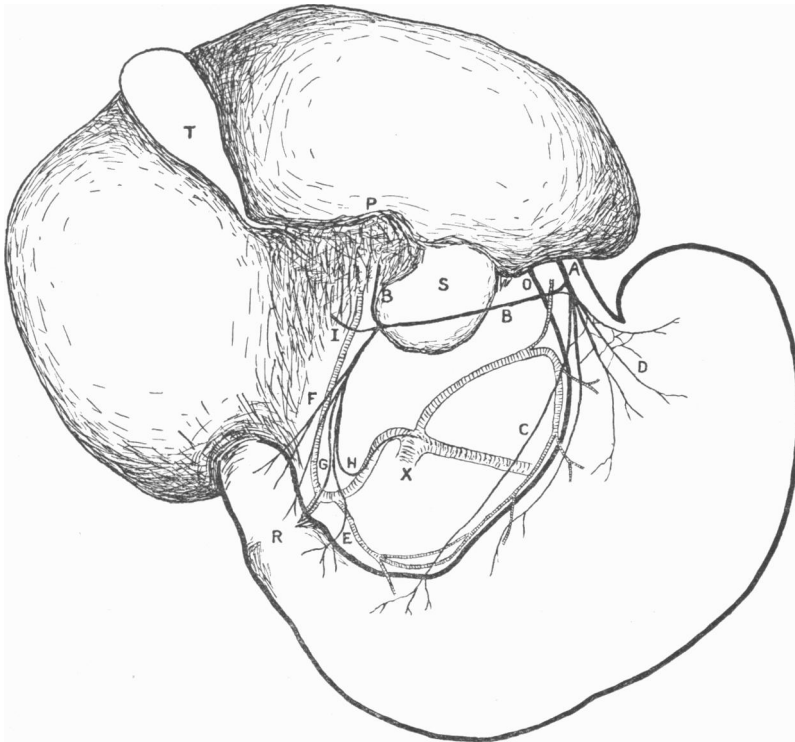

Fig. 10. Drawing to illustrate the distribution of the anterior vagal trunk. *A*, anterior vagal trunk. *B*, hepatic branch. *C*, principal anterior nerve of the lesser curvature. *D*, gastric branches. *E*, pyloric branch. *F*, duodenal branch. *G*, branch with gastro-duodenal artery. *H*, branch passing proximally on hepatic artery. *I*, branch to gall bladder. *X*, coeliac axis. *P*, porta hepatis. *S*, caudate lobe. *T*, gall bladder. *O*, oesophagus. *R*, pylorus.

METHOD

One vagus was divided, under aseptic conditions, in the cervical region of an animal, sufficient time was permitted to elapse to allow of the occurrence of degeneration of the nerve: the animal was then killed and sections of the vagi, of the anterior and posterior vagal trunks and of their branches were prepared and stained either by the Weigert method or by means of haematoxylin and Van Giesen. Four rabbits and two cats were used in these experiments.

The results fully confirmed the macroscopic findings and proved that each vagus nerve, through the oesophageal plexus, supplies fibres to both the anterior and posterior surfaces of the stomach.

Experimental stimulation of the vagi in the dog, cat and rabbit, has confirmed the statement of Ducceschi that either cervical vagus can innervate the whole stomach.

DISCUSSION

The results of this investigation on the distribution of the vagi nerves may be discussed under three headings: (1) the structure of the oesophageal plexus, (2) the branches and distribution of the anterior vagal trunk, and (3) the branches and distribution of the posterior vagal trunk.

(1) *The oesophageal plexus*

The descriptions of the general formation of the plexus given by Swan, Bourgery and Kollmann have been confirmed. It is important to note that the plexus possesses a most constant structural basis, which, as Kollmann stated, demonstrates definitely that each vagus supplies fibres to both the anterior and posterior surfaces of the stomach; the anterior and posterior vagal trunks formed from this plexus pass through the oesophageal opening of the diaphragm as single stems in the majority of cases: in none of my specimens was either trunk divided into more than two divisions. The descriptions found in the literature differ considerably as to the number of stems passing through the diaphragm, some even stating that the oesophageal plexus itself is continued through on to the cardia; it is probably rare to find more than two stems replacing either the anterior or posterior vagal trunk.

The structure of the oesophageal plexus in the cat and dog is essentially similar to that in man, though on a simplified scale. The description for the dog, given in the preceding pages, is similar to those of Kollmann, and Ellenberger and Baum. In the rabbit the structure of the plexus is seen to be somewhat different, but again each vagus is found to send fibres to both surfaces of the stomach; Jacobi's description of the oesophageal plexus of this animal is incomplete. It is interesting to note that the structure of the plexus in the sheep, as described by Hartung, closely resembles that of the rabbit.

(2) *The anterior vagal trunk*

The preceding findings are in general similar to those of Swan, Kollmann, Perman and Latarjet; some points however require discussion. The statement

of Kollmann that the anterior gastric plexus is variable and may be either present or absent is entirely confirmed and it is surprising that both Perman and Latarjet were unable to find such a plexus present. It is possible that individual observers differ widely as to the number of intercommunications necessary to constitute plexus formation; in some cases however one can have no hesitation in stating that a plexus is present, and in all instances at least one or two communications pass between neighbouring branches. The plexus, when present, is confined to those branches destined for the supply of the stomach; this statement is in accordance with the findings of the great majority of workers.

The anterior vagal trunk gives off one, sometimes two or three branches to the liver which cross to that organ in the lesser omentum. Swan and Kollmann show that these communicate with sympathetic fibres (the left hepatic plexus); the latter however noted a few cases in which he found these connections to be absent. Swan pictures twigs descending from this anastomosis to the pylorus and first stage of the duodenum: Latarjet states that the pylorus receives its entire nerve supply from above and believes them to be sympathetic, derived from nerves accompanying the hepatic artery (right hepatic plexus), and running a recurrent course in the lesser omentum. In my dissections such pyloric twigs are present and it would appear that certain of these are vagal in origin: in one case, Dissection III (fig. 4), a definite branch from the main branch of the anterior vagal trunk passes out into the lesser omentum and supplies the pylorus from above, without having any connection with sympathetic fibres or supplying a branch to the liver.

The main branch of the anterior vagal trunk lies between the two layers of the lesser omentum and follows the lesser curvature of the stomach. It reaches the region of the incisura angularis and its terminal twigs supply the pyloric antrum: in no case does this nerve send fibres as far as the pyloric canal or sphincter. Latarjet supports this view, but Kollmann and Perman, amongst many others, state that all the anterior surface of the pyloric region receives its nerve supply from this branch which runs along the lesser curvature. It may be noted that in the diagrams given by Perman this nerve terminates at some distance from the pylorus.

As regards the cat, dog and rabbit the findings are similar so far as the greater difficulties of dissection permit of accurate observation. The distribution follows the same plan but no plexus is ever present and Kollmann's observations support this: the main branches on the lesser curvature terminate in the pyloric antrum. Ellenberger and Baum, however, figure these in the dog proceeding to the pylorus, but Latarjet states that the pylorus, as in man, is supplied from above by the nerves of the liver.

(3) *The posterior vagal trunk*

The descriptions given by Perman and Latarjet of the gastric divisions are largely substantiated by my investigation. The statement of Kollmann

that a posterior gastric plexus may or may not be present is confirmed; if present it is confined to the gastric branches. This same worker finds that only the proximal half of the posterior surface of the stomach is supplied with vagal twigs: this is incorrect, for the nerves only fail to reach the pyloric canal and sphincter. The description given by Kollmann of the coeliac division is substantiated, although in the dissections of man it is difficult to differentiate between sympathetic and vagal fibres: in animals the vagal fibres are more distinct and can be traced out with greater ease. A point to emphasise is that the gastric division reaches the stomach by passing through the left gastro-pancreatic fold and its continuation, the falciform ligament; its branches do not lie in the lesser omentum. In the cat, dog and rabbit the distribution of the posterior vagal trunk is similar in its general plan; no posterior gastric plexus is ever present.

In general it may be stated that this investigation, except on a few points, confirms the work of Kollmann, whose work has not received due recognition in this country, and it is evident that, with the exception of the papers of Swan and Kollmann, no observer has attempted to give a full account of the course and manner of distribution of the vagi nerves in their lower thoracic and abdominal course[1]: the result of this has been that the importance of the influence of the oesophageal plexus on their distribution has been lost sight of.

The descriptions of the vagal distribution to the stomach given by Latarjet in his brief communications are exact and clear with the exception of one point—he does not state whether any vagal fibres reach the pylorus and one infers that the supply is entirely sympathetic. His nomenclature is useful, he names the main branch of the anterior trunk which passes along the lesser curvature "the principal anterior nerve of the lesser curvature," and the corresponding branch of the posterior trunk "the principal posterior nerve of the lesser curvature." These two nerves are conspicuous objects in any dissection.

Finally it must be noted that the descriptions of the oesophageal plexus as usually given are inaccurate and misleading, that the statement that the left vagus supplies the anterior surface of the stomach and the right the posterior, is incorrect, and that the variety of findings in regard to the anterior and posterior gastric plexuses depend on (a) their variability, and (b) the opinion of the individual observer as to what constitutes a plexus.

SUMMARY

1. The oesophageal plexus is in the structure and arrangement of its larger branches constant.

2. Two trunks arise from the oesophageal plexus, the anterior vagal trunk and the posterior vagal trunk; each trunk contains fibres of both left and right vagi nerves.

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[1] I have been unable to refer to the paper of Dorello.

3. These vagal trunks in the majority of instances pass through the oesophageal opening of the diaphragm each in the form of one or two stems.

4. Anterior and posterior gastric plexuses may or may not be present: the one may be present, the other absent. If present, their formation is limited to the branches destined for the supply of the stomach.

5. The manner of distribution of the vagal branches is in the main constant.

6. The main gastric branches lie in the neighbourhood of the lesser curvature.

7. The anterior vagal trunk supplies the anterior surface of the stomach as far as the pyloric antrum; it does not supply the pyloric canal and sphincter through those branches which lie along the lesser curvature.

This statement holds good for the posterior vagal trunk and the posterior aspect of the stomach.

8. The pyloric canal, sphincter, and first stage of the duodenum receive their nerve supply from above, receiving twigs from the vagal branches to the liver.

9. Vagal branches may be traced in man to the liver, pancreas and coeliac plexus; in addition, in animals, fibres may be traced to the suprarenal and renal plexuses, and to run with the hepatic, splenic and superior mesenteric arteries.

10. Sympathetic fibres derived from the coeliac plexus reach all regions of the stomach, twigs may be seen to unite with and run with vagal twigs.

11. The oesophageal plexus of the cat, and dog follows the same plan as that of man.

12. Gastric plexuses are not found in the dog, cat or rabbit.

13. The distribution of the vagi in the abdomen of the cat, dog and rabbit is essentially similar to that of man.

14. The vagal twigs in these animals remain more distinct from sympathetic fibres than in man, and their distribution may be more accurately followed distal to the coeliac plexus.

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