A MACROSCOPIC STUDY OF THE NERVE SUPPLY OF THE STOMACH

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The stomach is supplied by nerves which arise from various sources and pursue different pathways, and in this respect it resembles all the other important viscera, for it is becoming increasingly evident that multiple innervation is a characteristic feature of the autonomic system. The following observations are based on a series of fifteen dissections of infants, performed with the aid of a dissecting microscope, and it will be convenient to describe the sympathetic and parasympathetic supplies separately.

SYMPATHETIC

With certain exceptions, the great majority of the sympathetic filaments which supply the stomach are derived from the coeliac plexus. The exceptions are as follows:

(1) Filaments from the thoracic ganglionated trunks or splanchnic nerves supply the lower end of the oesophagus, and some of these may reach the cardia by passing down alongside the oesophagus (Text-fig. 1). Their insignificant size in most cases, however, is evidence of their relative unimportance.

(2) Other sympathetic fibres may be contributed by the infra-diaphragmatic part of the left greater splanchnic nerve, or by the upper end of the left lumbar ganglionated trunk. These usually unite with the gastric branches of the left phrenic plexus, or they may pass directly to the cardiac orifice.

(3) I have suspected for some years that the left phrenic nerve contributed branches directly to the stomach, probably sympathetic in nature, but only recently has it been possible to demonstrate the supply with absolute certainty. In this specimen (Text-fig. 2) the phrenic nerve pierced the diaphragm in the usual manner and broke up into three main branches, one passing to the right, one to the left, and one downwards and backwards. The last-named branch accompanied the left phrenic artery and soon gave off a filament on the left side to the diaphragm. A short distance below this point it bifurcated unequally, the larger filament entering the fibres of the right crus near the oesophageal hiatus, and the smaller filament continuing on its course alongside the vessel. About the level of the upper pole of the left suprarenal gland the latter nerve divided into two parts, one of which passed directly to the stomach, entering the viscus near the cardiac orifice. The other twig supplied the left suprarenal gland, and a very fine filament accompanied the artery to the coeliac plexus.

The gastric branches from the coeliac plexus accompany the vessels supplying the stomach, and the maximum number are found alongside the left gastric, hepatic, and phrenic arteries, but others accompany the splenic, right gastric, and gastro-epiploic vessels. Although the actual arrangement is fairly constant, in some cases the left gastric branches are most prominent, and in others the hepatogastric or some of the other gastric nerves, so that the relative importance of the supplies apparently varies in different specimens. Considering that they all arise from the same peripheral source and that a number of alternative pathways exist, this variation is not surprising.

(1) *The left gastric plexus*

The left gastric branches, one to four in number, lie near the artery, and as they approach the cardiac orifice they divide into a small proximal group for the cardiac end of the stomach, and one or two larger branches which run distally, between the layers of the lesser omentum, along the lesser curvature of the viscus (Text-figs. 3, 4; Pl. 1). The terminal twigs accompanying the main branch of the left gastric artery did not reach the pylorus in any specimen, but united with the nerve filaments lying alongside the right gastric artery. One of the proximal branches often encircles the cardiac orifice anteriorly to unite with a branch derived from the left phrenic plexus.

(2) *The hepatic plexus*

The hepatic plexus invariably supplies branches to the stomach, and they reach the organ along several channels:

(*a*) *The hepatogastric nerves.* The main supply consists of two or more filaments which arise from the portion of the hepatic plexus lying in the right margin of the lesser omentum, and pass to the lesser curvature between the layers of the lesser omentum, running parallel to, and often communicating with, the hepatic branches of the anterior vagal trunk which are running in the opposite direction (Text-figs. 1, 3; Pls. 1, 2). Reaching the lesser curvature they may supply filaments directly to the stomach, but they mainly unite with and reinforce the branches of the left gastric plexus. The uppermost branch supplies the gastro-oesophageal junction, and sometimes forms a loop in front of the cardiac orifice by uniting with a branch from the left phrenic plexus.

I suggest the name *hepatogastric* for these nerves, because they are gastric branches of the hepatic plexus, and they reach the stomach by passing between the layers of the hepatogastric ligament.

(*b*) *The right gastric nerves.* Other filaments from the hepatic plexus run with the right gastric artery, and they are more delicate than their left counterparts (Text-figs. 3, 5; Pls. 1, 2). They supply the upper parts of the pyloric region, and some filaments anastomose with the other gastric nerves nearby and with the terminal branches of the left gastric plexus.

(*c*) *The right gastro-epiploic nerves* come from the hepatic plexus via the gastroduodenal artery (Text-figs. 5, 6; Pl. 2). They are larger than the left gastro-epiploic branches, and there may be a single larger nerve or several smaller filaments. They accompany the vessels closely, and send branches upwards to the stomach, and filaments downwards alongside the epiploic vessels to the transverse colon.

(3) *The left phrenic plexus*

The left phrenic plexus supplies several filaments to the cardiac end of the stomach, and one of these is sometimes larger than the others, and passes around the left and anterior aspects of the cardiac orifice to unite with a filament from the left gastric plexus, or the uppermost gastric branch from the hepatic plexus (Text-figs. 1, 3; Pl. 1).

(4) *The right phrenic plexus*

The right phrenic plexus may supply the stomach and liver in the following curious manner, an arrangement which has been seen so far in four cases. One set of delicate nerves accompanies the right phrenic artery closely, but there may be another larger nerve arising from the upper part of the right coeliac ganglion, which lies a little apart from the artery on its inner side (Text-fig. 4). This latter nerve ascends towards the caval foramen, turns to the left behind it, and passes towards the oesophageal hiatus, being closely applied throughout this part of its course to the diaphragm. It supplies one or more slender twigs to the cardiac orifice, but the greater part of the nerve turns forward and passes between the layers of the upper part of the lesser omentum to enter the porta hepatis. In the region of the caval foramen it communicates with a branch or branches of the right phrenic nerve, and the phrenic ganglion is often found on, or close to, these anastomotic branches (Text-fig. 4).

(5) *The splenic plexus*

Delicate terminal branches of the splenic plexus accompany the short gastric and left gastro-epiploic arteries to the stomach, but in two cases a larger single filament was discovered arising above the superior border of the body of the pancreas (Text-fig. 7). This nerve passed upwards behind the lesser sac, to the left side of the left gastro-pancreatic fold, and then turned forwards between the layers of the gastro-phrenic ligament to supply the fundus of the stomach; one of its terminal branches communicated with a gastric branch from the posterior vagal trunk. Swan (1834) noted that the posterior vagal trunk might supply a twig to the splenic plexus, but in my two cases the filament from the splenic plexus was distinctly larger than the communication between it and the gastric branch of the posterior vagal trunk. Therefore part at least of this gastric branch cannot be derived from the vagal trunk, and must contain afferent or efferent fibres passing to or from the coeliac plexus.

PARASYMPATHETIC

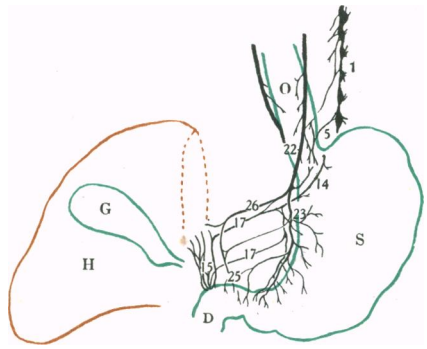
The parasympathetic supply to the stomach is conveyed by the vagi, and it is therefore necessary to describe briefly the terminal parts of these nerves. Considering their size and importance it is curious how many conflicting statements are still current about the lower vagi, and it is a sad reflexion on the neglect of the excellent work of Swan (1834) and Kollman (1860). Perman's (1916), Wertheimer's (1922) and McCrea's (1924) articles are also important contributions, providing not only an analysis of the previous literature, but also records of personal observations. With certain exceptions it has been possible to confirm these workers' findings, and to discover a few more facts about these interesting nerves.

The oesophageal plexus

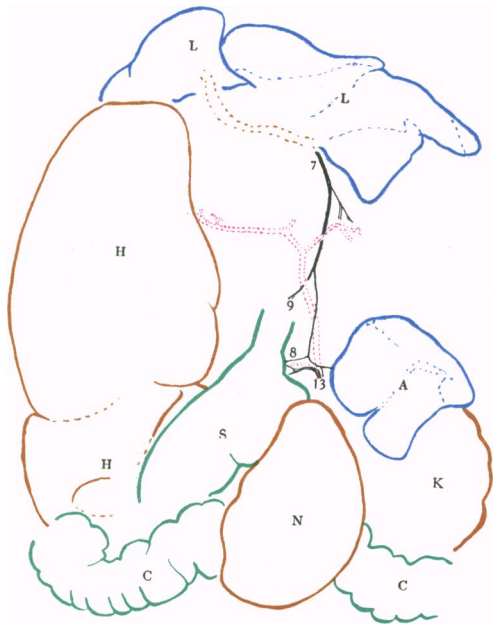
Below the roots of the lungs both vagi usually divide into from two to four main branches which lie in close relationship to the lower oesophagus (Text-figs. 6, 7. 8; Pl. 2). In this series of fifteen dissections the average number of branches on the right side has been three, and on the left side two. The right and left groups of fibres pursue an oblique course, so that the former come to lie on the posterior and the latter on the anterior aspect of the viscus, but one or more branches from the right vagus join the anterior half, and the left vagus contributes one or more branches to the posterior half of the plexus. All these branches are interconnected, so that a simple plexus gulae is formed, with rather open meshes. It is joined by sympathetic filaments from the thoracic ganglionated trunks and greater splanchnic nerves, and gives off numerous filaments which sink into the oesophageal walls. The relative absence of connective tissue between the constituent parts of the oesophageal plexus is rather characteristic, contrasting with the plentiful connective tissue which exists between the component parts of several other autonomic plexuses, such as the coeliac and hypogastric. Thus in most cases the plexus shows up clearly as soon as the mediastinal pleura is removed.

Immediately above the diaphragm, or actually within the oesophageal hiatus, the branches of the plexus reunite into two or more main trunks which enter the abdomen and lie anterior and posterior to the gastro-oesophageal junctions (Text-figs. 7, 8; Pls. 1, 2). There is no constant number, but it is unusual to find more than two on each aspect, and sometimes there is only one. Each trunk contains a proportion of fibres from both vagi, although right and left fibres preponderate in the posterior and anterior trunks respectively.

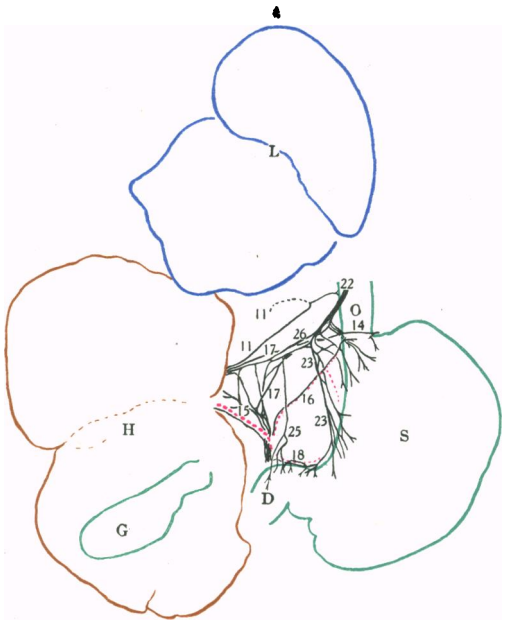
Although the arrangement above described is the commonest, two important variations must be mentioned. The left vagus sometimes passes mainly to the posterior aspect of the oesophagus, and the right to the anterior surface, where they form anterior and posterior plexuses in the usual manner. This has been seen once in thirty-four dissections (the gastric nerves have only been dissected out completely in fifteen cases, but actually thirty-four special



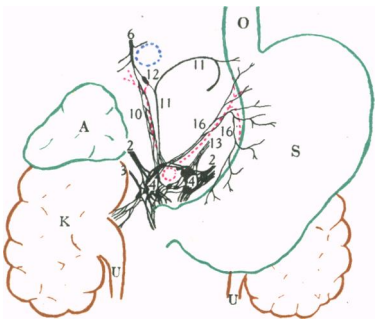
Text-fig. 1. A drawing from the photograph of a dissection. The left lobe of the liver has been removed to show the nerves between the layers of the lesser omentum.



Text-fig. 2. A line drawing from the photograph of a dissection. The left lobe of the liver has been displaced upwards and to the right, and the spleen has been drawn downwards and inwards, while most of the diaphragm has been removed; the two dotted lines to the right of the number 7 represent the cut edge of the diaphragm. The course of the left phrenic artery is indicated by the red dotted lines.



Text-fig. 3. A line drawing of the dissection shown in Pl. 1. The hepatic and right and left gastric arteries are represented by red dotted lines.



Text-fig. 4. A line drawing from the photograph of a dissection. The coeliac artery is represented by a red dotted circle, and the inferior vena cava by a blue dotted oval. The right phrenic and left gastric vessels are indicated by red dotted lines.

dissections have so far been performed). In another specimen no plexus gulae was formed, the two vagi being reconstituted into single trunks below the lung roots, whence they passed on to the oesophagus, the left being anterior and the right posterior (Text-fig. 1). Within the abdomen the two nerves were distributed in the ordinary manner.

The anterior vagal trunk

The anterior vagal trunk, which may be single (ten cases) or double (five cases), supplies several filaments to the cardiac orifice before dividing near the proximal end of the lesser curvature, into four groups of branches: (*a*) gastric, (*b*) pyloric, (*c*) hepatic, and (*d*) coeliac.

(*a*) *Gastric branches* (four to ten) are more numerous than the others and radiate to the lesser curvature, the uppermost fibres supplying the anterior aspects of the cardiac orifice and fundus, and the lowermost fibres reaching almost to the pylorus (Text-figs. 1, 5, 8; Pls. 1, 2). Frequently one branch is larger than the others and lies along the anterior part of the lesser curvature, between the layers of the lesser omentum, where it communicates by delicate tendrils with the adjacent sympathetic nerves and with the corresponding branch of the posterior vagal trunk (Text-figs. 1, 5, 8; Pl. 1). Latarjet (1921) and his co-workers describe this nerve as *the principal anterior nerve of the lesser curvature*, a clumsy appellation, but one which indicates its usual predominance in size; I suggest the term *greater anterior gastric nerve*, although this is also somewhat clumsy. The various gastric branches can be traced for some distance beneath the serous coat before they sink into the stomach musculature, and, although they communicate with neighbouring gastric nerves, I have never seen a true anterior gastric plexus either in these special dissections or in ordinary dissecting-room subjects. This is a point about which there is wide divergence of opinion, Swan (1834), Kollman (1860) and Spalteholz (7th English edition, no date) amongst others stating that plexus formation does occur, while Sappey (1872), Schäfer & Symington (1909), and Perman (1916) say there are no true gastric plexuses. McCrea (1924) found anterior plexuses in certain cases, but he remarks that the opinion of the individual observer as to what constitutes a plexus apparently varies, and thus the discrepancies may be explained.

(*b*) *Pyloric branches.* Pyloric branches are invariably supplied by the anterior vagal trunk, two being the common number (Text-figs. 1, 8; Pls. 1, 2). One arises high up near the left end of the lesser curvature, passes almost horizontally across between the layers of the lesser omentum towards its free edge, and then turns downwards on the left side of the hepatic artery to reach the pylorus and proximal part of the duodenum. It often bifurcates, sending one branch upwards to the liver and the other downwards to the pylorus, and it is always connected to the hepatic plexus by very fine fibres. The other pyloric branch usually arises from the greater anterior gastric nerve, about half-way along the lesser curvature, and it passes obliquely between the layers

of the lesser omentum to the pyloric antrum, some fibres reaching the pyloric sphincter. This branch thus arises at a lower level, but supplies the pylorus proximal to the branch first described.

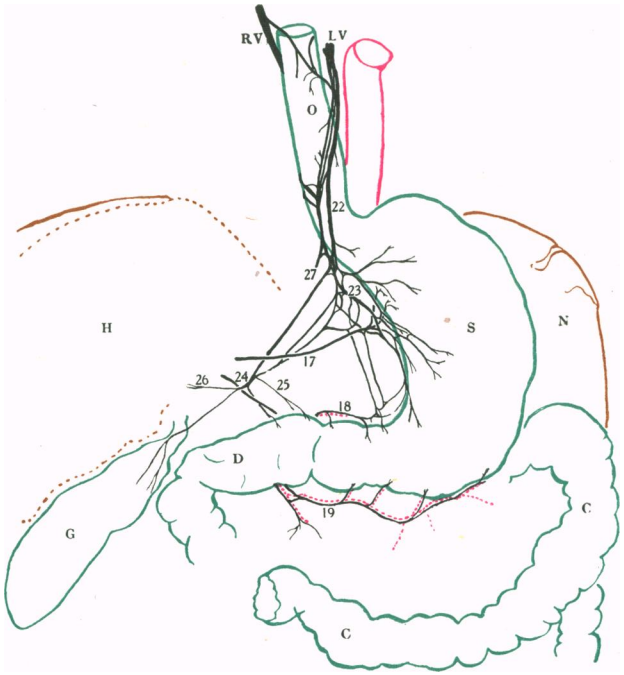
(*c*) *Hepatic branches.* Hepatic branches (two to four) are given off both from the stem of the anterior vagal trunk and from the greater anterior gastric nerve (Text-fig. 1; Pls. 1, 2). They pass to the right, and often blend with branches of the hepatic sympathetic plexus, but in some cases they pass directly to the porta hepatis without any significant communications with this plexus; the upper hepatic twig in particular often pursues an independent course. The nerves frequently divide on the left side of the hepatic artery, one branch passing upwards to the liver, and the other downwards to the pylorus or the coeliac plexus, while in one specimen the uppermost hepatic branch divided into three twigs; the first entered the porta hepatis, the second passed on to the cystic duct and gall-bladder, and the third descended alongside the hepatic artery to the pylorus (Text-fig. 5; Pl. 2).

(*d*) *Coeliac branches.* The anterior vagal trunk always sends twigs to the coeliac plexus, but judging from their size they only account for about one-quarter or one-third of the anterior trunk fibres, whereas the coeliac contribution from the posterior trunk usually represents about two-thirds of its bulk. The main coeliac branch(es) of the anterior vagal trunk arises near the cardiac orifice (Text-fig. 5; Pl. 2) and passes downwards with the left gastric artery, frequently blending with the corresponding coeliac division of the posterior vagal trunk. Other contributions to the coeliac plexus come from the hepatic or pyloric branches of the anterior trunk, and they reach the plexus alongside the hepatic artery.

The posterior vagal trunk

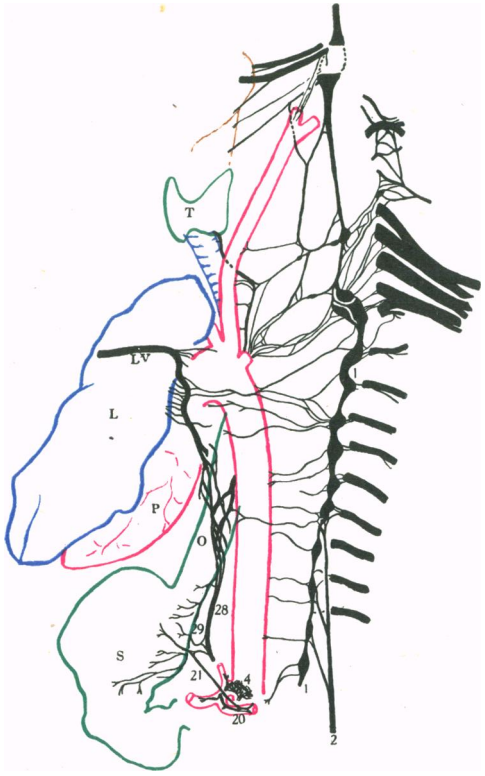
The posterior vagal trunk(s) may be single (eight cases), double (six cases), or triple (one case). Two main sets of branches, gastric and coeliac, are supplied by this trunk, and the coeliac division is usually the larger of the two (Text-figs. 6, 7).

The gastric branches. The gastric branches of the posterior trunk are distributed in a manner reminiscent of their anterior counterparts, although their area of supply is slightly less extensive (Text-figs. 6, 7). Thus a group of fine filaments radiates to the cardiac orifice and fundus, and one or more larger nerves proceed along the posterior margin of the lesser curvature. As on the anterior aspect there are usually several nerves, but one of the groups is always larger than the others. Latarjet (1921) and his co-workers refer to this nerve as *the principal posterior nerve of the lesser curvature*, but the term *greater posterior gastric nerve* might be substituted with advantage. In some dissections it forms a very conspicuous object, and in one specimen it seemed to account for about one-half of the fibres of the posterior vagal trunk (Text-fig. 6); not far from its origin, however, it gave off a branch which proceeded downwards alongside the left gastric artery to the coeliac plexus (Text-fig. 6). This arrangement has been seen in several other specimens—namely that a

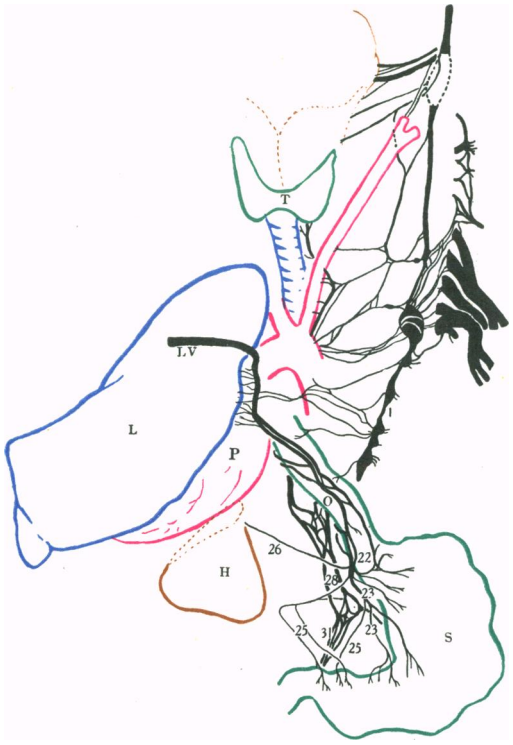


Text-fig. 5. A line drawing of the dissection shown in Pl. 2. The right gastric and gastro-epiploic vessels are indicated by red dotted lines.

Text-fig. 6. A line drawing from the photograph of a dissection. The stomach has been turned over to the right so that the posterior surface is exposed. The left half of the liver has been removed and the remainder pulled downwards. The gastric and right gastro-epiploic arteries are indicated by red dotted lines. To prevent confusion, gastric branches of the anterior vagal trunk and of the left gastric and hepato-gastric nerves have not been filled in.



Text-fig. 7. A line drawing from the photograph of a dissection. The stomach has been partly rotated to the right in order to show the posterior surface. The left lung has also been displaced to the right to show the cardiac, pulmonary, aortic and oesophageal nerves.



Text-fig. 8. A line drawing from the photograph of a dissection. The left lung has been turned to the right and the oesophagus has been displaced slightly to the left to display the posterior half of the oesophageal plexus. Note the plexus form assumed by the coeliac division of the posterior vagal trunk; careful dissection reveals that this is a common occurrence. To minimize confusion the left gastric nerves are not indicated.

bundle of fibres, ultimately destined for the coeliac plexus, runs for a short distance as a constituent part of the greater posterior gastric nerve, and then becomes separated from this nerve near the upper end of the lesser curvature. This coeliac contribution sometimes rejoins the main coeliac division of the posterior vagal trunk, or may pursue an independent course, as in the case illustrated. Slender hepatic twigs also arise occasionally from the gastric division, and pass to the porta between the layers of the lesser omentum. The posterior gastric nerve gives off branches at intervals which pass to the stomach, but the terminal branches extend only to the pyloric antrum, failing to reach the pyloric sphincter. They communicate with the adjacent gastric nerves, but in no case was there a true posterior gastric plexus in this series of dissections. In this respect, as in the case of the anterior gastric plexus, there is wide divergence of opinion, some saying there is plexus formation and others that there is none. As these discrepancies are possibly due to the fact that no two observers agree exactly about the size or number of the intercommunications necessary to constitute plexus formation, it should be stated that in this investigation unless a definite nerve network was found, and not merely occasional delicate intercommunications, it was decided that no plexus existed. The gastric nerves usually pursue a relatively independent course, communicating only by filaments distinctly finer than the parent stems, and if this be regarded as plexus formation, then it would be true to say that both anterior and posterior gastric plexuses exist.

The coeliac branches. The coeliac branches are larger than the gastric in most cases, and in only one specimen were the gastric and coeliac divisions about equal in size (Text-fig. 6); in this case, however, as has been already explained, the gastric branch gave off a coeliac contribution near the proximal end of the lesser curvature, and it was stated that similar, though smaller, coeliac branches of the greater posterior gastric nerve have been detected in several other specimens. At first sight the coeliac division appears to consist of a single nerve, but careful dissection shows that it is often composed of three or four branches lying close together, and united by large intercommunications so that a plexus is formed (Text-figs. 6, 8). All branches end in the coeliac plexus, part passing to the right half and part to the left, but so far it has not been possible to determine the ultimate destination of the individual branches because of the multiple intricate interconnexions in the coeliac plexus.

From this account, it will be observed that the variety of sources from which gastric nerves are derived is remarkable, and their number is evidence of their importance.

SUMMARY

1. The stomach, in common with other important viscera, is supplied by nerves from multiple sources.

2. The sympathetic supply is derived mainly from the coeliac plexus, and the

majority of the fibres accompany the various gastric arteries. Other inconstant filaments are derived from the left phrenic and splanchnic nerves and the thoracic and lumbar portions of the left ganglionated sympathetic trunk.

3. Judging by their size, the more important contributions are derived from the left gastric, hepatic and left phrenic plexuses, and the manner in which they reach the stomach is exactly described.

4. The branch of the left phrenic nerve supplying the right crus of the diaphragm has been shown to contribute a direct branch to the cardiac end of the stomach.

5. It is suggested that the important group of branches passing from the hepatic plexus to the stomach between the layers of the hepatogastric ligament should be termed the *hepatogastric* nerves.

6. A special derivative of the right phrenic plexus which pursues a curious course and supplies the cardiac orifice of the stomach and the liver is described and illustrated.

7. The splenic plexus has been found occasionally to contribute another gastric branch, in addition to the short gastric and left gastro-epiploic nerves.

8. The parasympathetic supply is vagal in origin, so the distribution of these nerves in their lower course is discussed.

9. It is pointed out that the normal arrangement of the right vagus passing posterior and the left vagus anterior to the oesophagus may be reversed, and that plexus gulae formation is not invariable, the nerves sometimes becoming reconstituted below the lung roots to form single trunks.

10. It is suggested that the chief gastric branches of the anterior and posterior vagal trunks should be named the *greater anterior* and *posterior gastric nerves.*

11. The distribution of the pyloric branches from the anterior vagal trunk is described, and one case is recorded where a nerve derived from the anterior vagal trunk gave off twigs simultaneously to the pylorus, liver and gall-bladder.

12. No true anterior or posterior gastric plexus has been seen in any dissection.

13. The coeliac division of the posterior vagal trunk is more often a plexus than a single nerve.

14. In some specimens fibres ultimately destined for the coeliac plexus run for part of their course with the greater posterior gastric nerve.

The observations described above have all been checked on the actual dissections by Profs. A. Low, J. R. Learmonth or R. D. Lockhart, and I wish to express my thanks for their valued help. The Medical Research Council have generously defrayed most of the expenses of the investigation. I wish also to acknowledge a substantial grant from the University of Aberdeen towards the cost of the illustrations.

KEY TO ILLUSTRATIONS

1. Ganglionated sympathetic trunk
2. Greater (thoracic) splanchnic nerve
3. Lesser (thoracic) splanchnic nerve
4. Coeliac plexus
5. Filaments of supra-diaphragmatic origin supplying the gastro-oesophageal junction
6. Right phrenic nerve
7. Left phrenic nerve
8. Gastric branch of left phrenic nerve
9. Right crural branch of left phrenic nerve
10. Right phrenic plexus
11. Gastric and hepatic branch of right phrenic plexus
12. Phrenic ganglion
13. Left phrenic plexus (lower part)
14. Loop in front of cardiac orifice connecting gastric branch of left phrenic plexus and uppermost hepatogastric nerve (or a branch of the left gastric plexus)
15. Hepatic plexus
16. Left gastric nerve(s) (plexus)
17. Hepatogastric nerve(s)
18. Right gastric nerve(s) (plexus)
19. Right gastro-epiploic nerve(s)
20. Splenic nerves (plexus)
21. Gastric branch of splenic plexus arising above superior border of body of pancreas
22. Anterior vagal trunk
23. Greater anterior gastric nerve
24. Common nerve supplying liver, gall bladder and pylorus
25. Pyloric branch(es) of anterior vagal trunk
26. Hepatic branch(es) of anterior vagal trunk
27. Coeliac branch of anterior vagal trunk
28. Posterior vagal trunk
29. Greater posterior gastric nerve
30. Coeliac branches arising from greater posterior gastric nerve
31. Coeliac division(s) of posterior vagal trunk

A Suprarenal gland
C Colon
D Duodenum
G Gall bladder
H Liver
K Kidney
L Lung
N Spleen
O Oesophagus
P Pericardium
R Pancreas
S Stomach
T Thyroid gland
U Ureter
RV Right vagus nerve
LV Left vagus nerve

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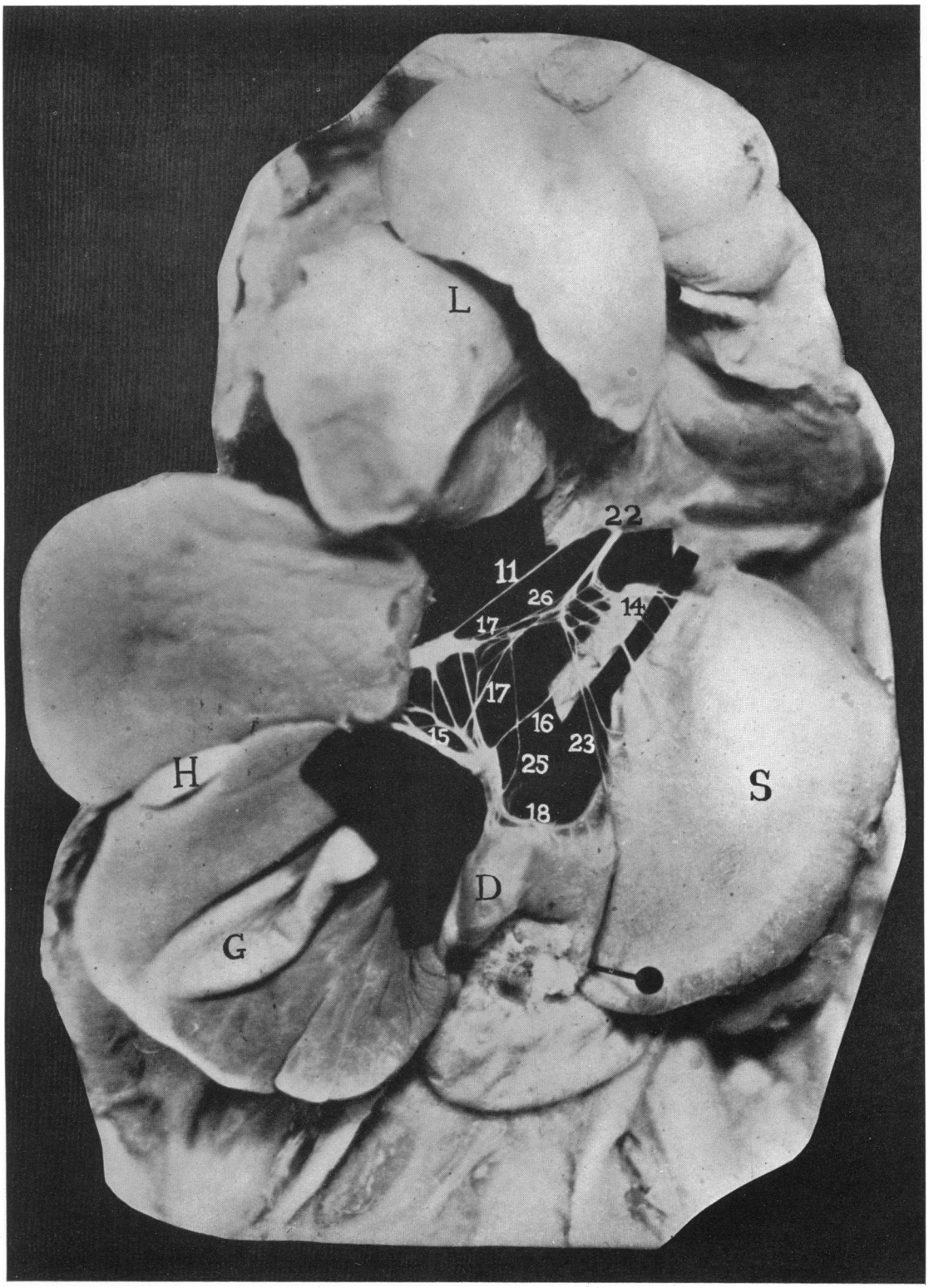
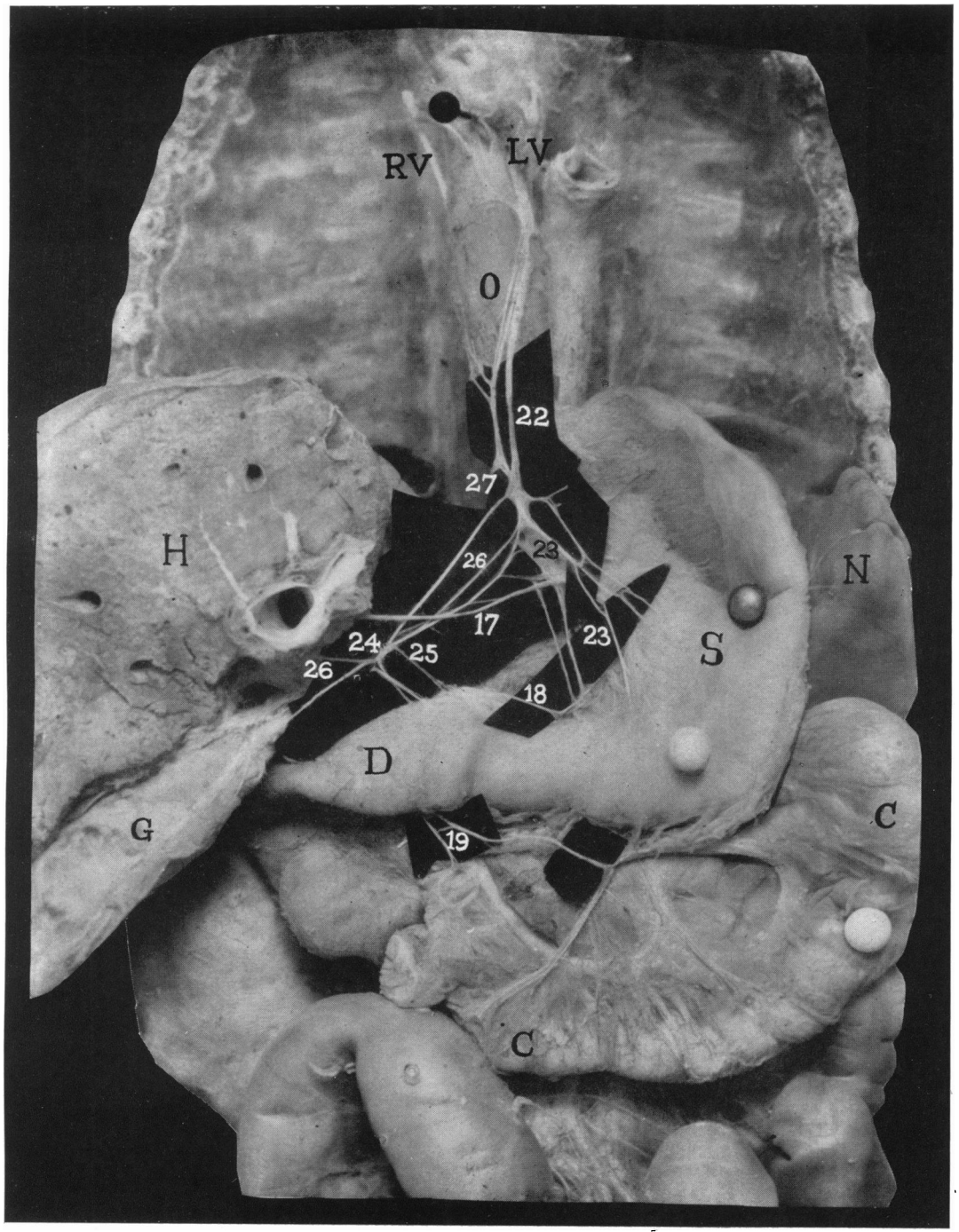


MITCHELL—THE NERVE SUPPLY OF THE STOMACH



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EXPLANATION OF PLATES 1 AND 2

PLATE 1

In order to expose the cardiac end of the stomach the liver has been rotated slightly, so that its left lobe lies above the right.

PLATE 2

The left half of the liver has been completely removed to display the cardiac end of the stomach and the nerves between the layers of the lesser omentum.

Note. Owing to the high cost of reproduction, it has been possible to reproduce only two of the photographs from which the line drawings were made.