The development of the arteries of the abdomen and their relation to the peritoneum / by C.B. Lockwood ; communicated by W.S. Savory.

Contributors

Lockwood, Charles Barrett, 1856-1914.
Savory, William Scovell, 1826-1895.
Royal College of Surgeons of England

Publication/Creation

[London] : [Royal Society of London], 1885.

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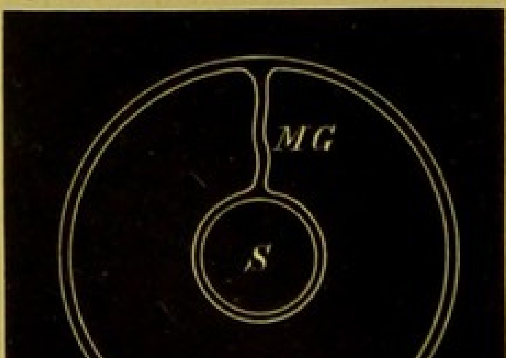
much as they lead up to the points towards which it is desired to draw attention.

A section through the abdomen at about this period (the third or fourth day) displays a body-wall enclosing a pleuro-peritoneal cavity; and in the interior of this an alimentary tube suspended by a mesentery. A more minute examination of the mesentery shows that it is attached to the spine above: that its surface is covered with flattened cells, and that its interior consists of mesoblastic tissue and blood-vessels. The latter spring from a large artery, the aorta, which runs along the base of the serous fold. The vessels of the gut are not merely derived from one or two branches arising from particular parts of the aorta, but are represented by vessels which descend at intervals from the parent trunk. Later it will be evident that only a few of these mesenteric vessels persist, and that the various parts of the alimentary canal retain a supply commensurate with their requirements. Moreover, it will be seen that the development of a great organ, such as the liver, pancreas, or spleen, in intimate relation with the bowel, has an important influence in determining the size of the vessels which pass through the mesentery.

Again, referring to the section through the third or fourth day chick, the following points are easily ascertained. The mesentery and intestine hanging into the pleuro-peritoneal cavity divide it, roughly speaking, into two halves; a right and left (Diagram 1). Of course it follows that the blood-vessels which it contains are bounded on each side by these halves of the peritoneal cavity. As long as this arrangement continues, nothing could be simpler than the relations of the vessels; but complications soon occur, and it will now be attempted to state in detail what they are and how they are produced.

For the sake of clearness, the events which take place in that part of the mid-gut which afterwards becomes the stomach may be con-

Diagram 1.

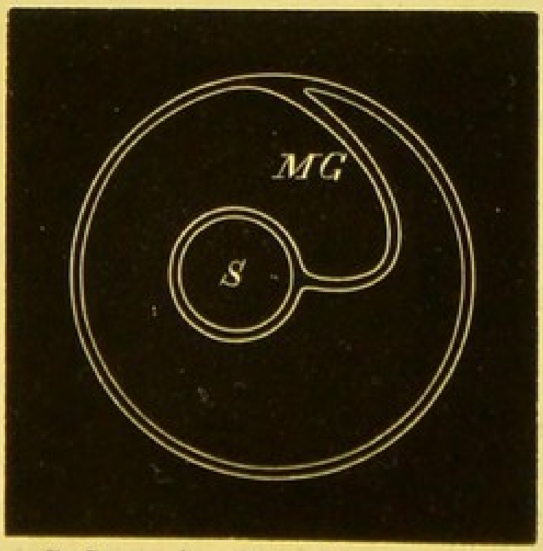


S. Stomach. *MG.* Mesogastrium.

sidered first; although it may be remarked that a great many of the events which are about to be mentioned are in progress at the same time.

The position of the stomach is indicated by an enlargement of the anterior portion of the mid-gut. This organ, like the remainder of the bowel, is fastened to the spine by a mesentery, and simply hangs suspended in the pleuro-peritoneal cavity (Diagram 1). This position is altered by the stomach turning upon its right side. The mesentery, or mesogastrium as it will be called in future, is implicated in this change; instead of descending vertically from the spine to the stomach, it becomes looped (Diagram 2). Owing to these movements of the stomach and mesogastrium the cavity which they partitioned becomes different. There is no longer a right and left division of the peritoneal sac, but a part in front and to the left of the stomach and mesogastrium, and a part behind and to the right. The space which is behind the stomach, and which has the mesogastrium for its left boundary, represents what afterwards is the lesser cavity of the peritoneum. It need not be repeated that blood-vessels pass through the mesogastrium to the stomach, and are of necessity involved in the changes which have just been described. Their course, instead of being straight, forms a curve. The relations of these altered vessels to the subdivisions of the peritoneal cavity require to be noted; it is evident that to reach their destination they now pass round the left boundary of the future lesser sac.

Diagram 2.



S. Stomach. *MG.* Mesogastrium.

All the changes which have been narrated occur at very early stages of development; subsequent events do not produce any great alterations. Later it will be seen that the stomach becomes less vertical, and its mesentery further modified; but the changes which the mesogastrium undergoes are very striking. They have been fully discussed before,* so that it does not seem necessary to do more than allude to them briefly. Stated as shortly as possible, it may be said that at the œsophageal and pyloric ends of the stomach the mesogastrium remains short, but near the middle elongates and becomes the great omentum. This anomalous structure afterwards enters into relation with the transverse colon; but at present the manner in which this is brought about need not be discussed.

This much having been premised, it may be inquired whether these observations are applicable to the adult subject. The mesogastrium having been identified with the great omentum, it remains to be seen if the blood supply of the stomach still passes through it. The gastric artery certainly conforms to the conditions. This artery begins behind the peritoneum, and runs between two layers of this membrane to reach the œsophageal end of the stomach. These folds of peritoneum represent the upper part of the mesogastrium, and are continuous below with the great omentum. To confirm these statements the lesser sac of the peritoneum should be opened; a hand passed within it towards the right of the œsophagus enters the concavity of a loop which the gastric artery makes; a hand introduced into the greater sac, to the left of the œsophagus, touches the convexity of the loop. When the anatomy of the gastric artery is compared with the original vessels of the mesentery its close resemblance to them is clear; the modifications which have occurred are comparatively insignificant. As it has been explained how the mesogastrium forms the left boundary of the lesser peritoneal cavity, it therefore seems unnecessary to enter into details concerning the relations of the vessels which it contains to the greater and lesser sacs.

If the arteries of the stomach were taken in detail the vasa brevia would come next, and afterwards those near the pylorus. Passing over the vasa brevia, for the moment, the following question seems to demand an answer. If the mesogastrium originally contained numerous vessels, how is it that, with the exception of the vasa brevia, none are found between the œsophagus and pylorus? Generally speaking, structures receive their blood supply by the nearest route, and exceptions to this rule can usually be accounted for. The elongation of the mesogastrium, to form the great omentum, is so excessive that it might almost be anticipated that none of its vessels would persist. Whatever the probabilities may seem, it has always been recognised that the omentum contains enormously long vascular loops, which extend from the curve of the stomach to the transverse colon; they are usually spoken of as being the longest arterial loops in the body. Although these vessels appear to be more for the supply of the

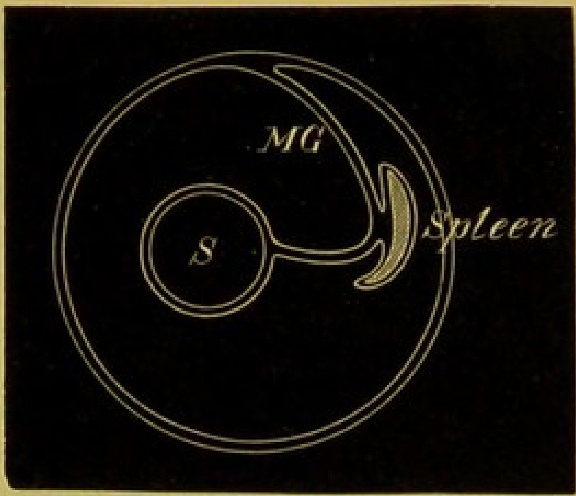
* "On the Development of the Great Omentum and Transverse Meso-colon," By C. B. Lockwood, "Proc. Roy. Soc.," vol. 35, p. 279.

omentum than of the stomach, yet it does not seem unreasonable to argue that they represent the original vessels of the mesentery.

If the course of the gastric artery, through the mesogastrium, has been followed, that of the splenic offers fewer difficulties. Exactly similar principles of development apply to it.

If the mesogastrium of a human embryo about 2 inches long be examined the following facts may be easily observed. Near the œsophagus the mesogastrium is comparatively short, but at the junction of the anterior with the middle third of the stomach it is longer, and the rudiment of a spleen may be distinguished between its layers. This organ is developed from the mesoblast which exists between the layers of the mesogastrium. It will be remembered that a portion of this tissue had previously become differentiated into the blood-vessels of the mesogastrium. Whether the spleen and its blood supply are formed at the same time and from the same tissue, or whether this organ appropriates some of the vessels which the mesogastrium previously contained, would be hard to say. The fact remains that the mesoblast from which this organ is developed is in direct continuity, behind, with that which surrounds the aorta, in front, with that which forms the wall of the stomach; there is no anatomical reason, therefore, why either of the above events might not occur. As soon as the spleen appears blood-vessels can be seen extending to it from the aorta, and onwards to the stomach. Entirely situated between the layers of the mesogastrium the spleen derives the whole of its blood supply from vessels passing through it. At the period at which the spleen is formed the mesogastrium has become involved in the change of position which the stomach undergoes. Owing to the turning of this organ upon its right side, the mesogastrium forms a fold the convexity of which is towards the left. The portion of the general peritoneal cavity included in the concavity of the fold represents the lesser sac. Now the spleen appears at the convexity of the loop, so that the portion of mesogastrium which extends from the spine to the spleen forms the left boundary of the lesser cavity, and that which passes from the spleen to the stomach constitutes the gastrosplenic omentum (Diagram 3). The application of these facts to the course of the splenic artery is not difficult. As this vessel runs in the mesogastrium it ought to commence behind the lesser peritoneal sac, and pass in its left boundary to reach the spleen. It is also clear that a portion of the greater cavity, that which lies between the posterior surface of the mesogastrium and back wall of the abdomen, should be behind the artery. That this is so may easily be ascertained by examining a human fœtus at about the full term. At this period the mesogastrium is well marked, and the splenic artery plainly between its layers. Even in the adult there is a well marked recess, so that, by placing one hand in the lesser sac and another behind the spleen in the greater, the artery in question may be grasped. Recent works on anatomy (*e.g.*, "Quain's Anatomy," Ninth Edition, 1882, vol. ii, p. 729, fig. 621, &c.) delineate the peritoneum in accordance with the above description. The process of development which has been described seems to afford an explanation of the very complicated relations of this artery, both to the peritoneum and to its greater and lesser cavities.

DIAGRAM 3.



S. Stomach. *MG.* Mesogastrium.

The arteria vasa brevia and gastro-epiploica sinistra are naturally the next to demand attention. It has been pointed out already that the gastro-splenic omentum is simply that part of the mesogastrium which lies between the spleen and the stomach. Blood-vessels are present in the mesentery of the stomach long before the appearance of the spleen, but it does not seem possible to say whether the vasa brevia are the representatives of these, or whether, as was remarked before, they might have been developed in connexion with the spleen itself. Similar doubts appear to exist when the epiploic arteries are in question; how far they are prolongations of the original arteries of the mesogastrium, or to what extent they are developed in the mesoblast which surrounds the stomach. A solution of this point would in no way affect what has been said about the course and relations of the splenic artery itself. This vessel is exceedingly like the gastric, for it has a similar origin and similar course through the mesogastrium.

The arteries in the vicinity of the pylorus are the next to demand notice. The development of the liver and lesser omentum has a profound influence upon these, and therefore requires ample consideration. Owing to difficulties which have been mentioned before their development will be studied in the chick. The very earliest stages of the development of the liver determine its arterial supply. A transverse section through an embryo chick at about the third day of incubation, displays the alimentary canal suspended from the vertebral region by a long mesentery. The liver commences as a protrusion from the wall of the intestine, and owing to the rapidity of its growth the organ soon attains considerable size. Numerous blood-vessels are present in the mesentery which unites the liver and intestine to the spine, and the corpuscles which they contain may be seen to enter into intimate relation with the hypoblastic cells which form the liver substance. This observation is of the greatest importance, for it shows that from its earliest appearance the liver obtains a part of its blood supply from the vessels of the mesentery. Continuing to watch the changes which occur, it will be found that the growth of the liver is very rapid, and that, after a while, it gradually becomes constricted at its junction with the alimentary canal. Whilst this constriction is being formed, the convexity of the growing liver unites with the front wall of the abdomen. The histological changes which accompany these processes are of some importance. The cells which cover the surface of the liver and adjoining parts assume a flattened appearance, and are undistinguishable from those which line the remainder of the pleuro-peritoneal cavity. In other words, the surface of the liver becomes covered with peritoneum. The constriction between the stomach and the liver, at the same time, becomes thinner, and its surface converted into serous membrane. If, at this stage, a recapitulation be permitted, it is evident that the section shows, from the spine forwards, mesentery, intestine, constriction, liver, and attachment of liver to front wall of abdomen. Both Gegenbaur ("Elements of Comparative Anatomy," translated by F. J. Bell, p. 565) and Balfour (" Comparative Embryology," vol. ii, p. 623) point out that this is the usual condition in the vertebrates. The identity of the various parts which have been mentioned has also been recognised by these authors, and seems quite obvious; the mesentery and intestine require no further remark; the constriction between the liver and the bowel corresponds to the lesser omentum, and the part uniting the liver to the front wall of the abdomen is the same as the falciform ligament.

A little consideration will show that although the preceding events have been observed in other vertebrates, yet they are applicable to the human subject. Owing to alterations which take place in the mesentery this is not so easy in the adult, but at about the fifth month of intrauterine life the whole intestine, including the stomach and duodenum, has a well marked mesentery, and it may be seen near the pylorus that the mesoduodenum, duodenum, lesser omentum, liver, and falciform ligament, form an anatomical sequence.

These preliminary facts may now be used in an endeavour to elucidate the course of the hepatic artery.

It has been previously stated that from its earliest appearance the liver derives a portion of its blood supply from the vessels of that part of the alimentary tract from which it grew; and the mesentery was stated to be the route by which it arrives at its destination. Now it is clear that, as development progressed, this supply, besides passing through the mesentery, would have to extend through the constriction which forms between the liver and intestine. In the human subject the duodenum represents that part of the alimentary tract which gives origin to the liver; and, therefore, it seems reasonable to search in its neighbourhood for a vessel which fulfils the conditions which have been laid down. The hepatic artery leaves nothing to be desired; arising behind the peritoneum it runs to the duodenum, and distributes branches to the stomach and intestine; thence it passes onwards through the lesser omentum to the liver, and it is hardly necessary to remark that the lesser omentum corresponds to the constriction which has just been spoken of. One point with regard to the anatomy of the hepatic artery seems to call for explanation and comment; its passage through the mesentery. In the adult the mesoduodenum is often of insignificant size, so that it is not easy to demonstrate the artery passing through it. At about the middle of intrauterine life the mesoduodenum is long, and no such difficulty exists. Perhaps this observation is strengthened by an examination of the course of the vessel in the shrew. In this animal the whole alimentary tract retains the mesentery, and I have satisfied myself that the hepatic artery passes through it before reaching the liver.

If it is true that the hepatic artery is the representative of one of the original vessels of the mesentery, many of its peculiarities may be explained. Instead of one the liver may have two or even three arteries (Cruveilhier, "Traité d'Anatomie Descriptive," vol. iii, p. 67). When this is the case the additional vessels may arise from the aorta and reach the liver in the usual way, or they may take origin from the gastric or superior mesenteric arteries; both of which, it is significant to remark, formerly belonged to the mid-gut. Evidently the organ may appropriate more than one of the original vessels of the mesentery.

That the hepatic artery should distribute branches to the stomach and duodenum need not excite surprise; before the appearance of the liver it performed no other function than to supply that part of the intestine which afterwards becomes converted into those organs.

So far, in order not to introduce needless complications, no reference has been made to the aperture which is called the Foramen of Winslow. The development of the hepatic artery is a factor, but not an essential factor, in its formation. To explain the origin of the Foramen of Winslow, the changes of position which the liver, stomach, and lesser omentum undergo, require to be considered. In a human embryo, an inch or an inch and a-half long, the stomach is almost vertical. It has been remarked before that the space behind it corresponds to the lesser cavity of the peritoneum. The communication between this and the greater sac lies between the right border of the stomach and lesser omentum and the posterior wall of the abdomen. Now at this early stage of development the liver is of enormous size, and nearly fills the abdominal cavity, descending as low as the pubes. In consequence its transverse fissure occupies an exceedingly low position. Afterwards the relative size of the liver diminishes, and it may be said to retreat beneath the ribs and costal cartilages. It seems reasonable to argue that when the liver makes this ascent it must needs take the lesser omentum, pylorus, and hepatic artery up with it; and it would further follow that the stomach would become more nearly horizontal, and the hepatic artery acquire an upward direction. It is these events which cause the Foramen of Winslow to assume its permanent appearance and position.

Three important arteries, the gastric, splenic, and hepatic, have been passed in review. From the details of their development principles of wide applicability may be deduced.

First. That they were originally derived from the dorsal aorta for the supply of the mid-gut.

Second. That they reach their destination by passing through the mesentery.

Third. That they participate in all the changes the mesentery undergoes.

Fourth. That if an organ is developed in the mesentery or from the gut, it obtains, part at least, of its vascular supply from the vessels of the mesentery, or from those of the gut from which it sprung.

The attempt may now be made to apply these principles to the remainder of the human alimentary canal. Before discussing in detail the arteries of the intestines and their appendage, the pancreas, the development of these organs requires a passing notice. The formation of the large and small intestines has been fully described elsewhere (*e.g.*, Balfour, Gegenbaur, Quain, &c.). Recapitulated as briefly as possible, it may be stated that in human embryos an inch long the alimentary canal forms a loop extending from the stomach to the pelvis. The convexity of this loop is situated in the large aperture which afterwards becomes the umbilicus; its concavity is fastened to the spine by a considerable mesentery. A small protrusion appears about the middle of the intestine, and marks the commencement of the cæcum and vermiform appendix. As the calibre of the upper and lower parts of the bowel are the same, the outgrowth determines its division into small intestine and colon.

The developmental changes which afterwards occur in the upper part are so slight that they do not seem to demand further comment. An exception may be made in the case of the duodenum, for owing to the presence of the pancreas, the arteries in its neighbourhood are more complicated.

As far as the duodenum itself is concerned, it has been explained why the hepatic artery should send branches to it; the *rationale* of its supply from the superior mesenteric is so obvious that it does not seem to require notice. It would be hard to explain why parts of the duodenum cease to have a mesentery, but the fact of the disappearance of this serous fold can have no influence upon the sources of its blood supply; that was determined long before the mesentery became obliterated.

With regard to the arteries of the pancreas, one or two points await solution. At first it may not be evident why it should be supplied by the vessels of the duodenum and spleen. It is well recognised that the pancreas commences as a cæcal prolongation from the duodenum. In a human embryo about 2½ inches long the elongated mesogastrium, *i.e.*, great omentum, has not yet involved the transverse colon; and when this membrane is lifted upwards, it may be seen continuous with the mesoduodenum. The pancreas, already of considerable size, stretches from the duodenum into the mesoduodenum, and onwards into the mesogastrium,* where it applies itself to the spleen, previously described as being between the layers of this membrane. The splenic artery may be seen as a delicate streak in the mesogastrium close to the pancreas, and is at this time one of its most available sources of blood supply. It is evident that the fact of this organ being at one time between the layers of the mesentery explains why it should be supplied by its vessels, such as the splenic and duodenal; it also explains why, as Haller (quoted by Cruveilhier, vol. iii, p. 68) points out, the pancreas may have a large artery (pancreatica suprema) arising from the cæliac axis, superior mesenteric, or aorta. It will be remembered that the original vessels of the mesentery are numerous, and that even the liver sometimes appropriated more than one; evidently the same is the case with the pancreas. In conclusion, as regards the position of the pancreas between the layers of the mesentery, it is permanent in some animals, *e.g.*, the hedgehog (see also sp. 780A and 781A, R. C. S. Museum). The ultimate relations of this organ to the serous membrane may be conveniently discussed a little further on.

* July 6th, 1885.—This is exactly the anatomical relation which has been described by Professor Anderson as existing in the seal ("Journal of Anatomy and Physiology," xix, p. 228).

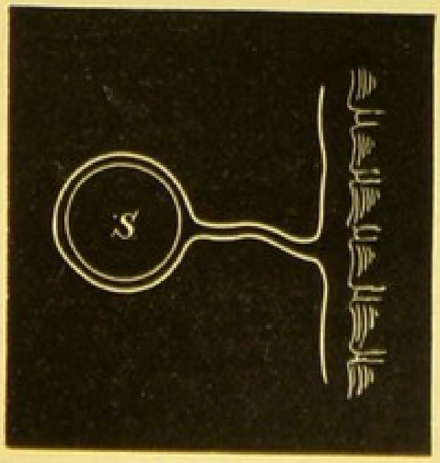
The colon, sigmoid flexure, and rectum are the only parts of the alimentary canal which await examination. When the primitive intestinal loop was mentioned, a part which extended from the pelvis to the cæcal protrusion was left. Keeping in view the fact that the bowel has an abundant mesentery, it remains to be explained how it becomes converted into the ascending, descending, and transverse colons, and how its conversion affects its vascular supply. The simplest way seems to be to trace the movements of the cæcum. At its first appearance this *cul-de-sac* is within the wide umbilical aperture, but as the intestine elongates it performs a tour round the abdomen; from the umbilicus it passes upwards towards the stomach; from thence it journeys into the right hypochondrium, forming the transverse colon, and descending into the right iliac region completes the ascending portion of the gut. When the colon was straight and indistinguishable from the rest of the alimentary tract, its vascular supply consisted simply of vessels which descended along the mesentery; as the bowel travels round the abdomen it carries both mesentery and blood-vessels with it. The peculiarities which are produced in this manner are so slight that they do not seem to demand further notice.

There is, however, an exception in the case of the middle colic artery, for both the anatomy and the development of the mesocolon, in which it lies, are open to discussion. These questions have already been argued at some length by the author in the paper previously alluded to (p. 477), so that in the present instance they may be briefly stated.

As a review of the formation of the omentum and transverse mesocolon naturally leads up to the points at issue, it is convenient to begin by discussing it.

Both the structures in question were mentioned when the development of the stomach and colon was being described (p. 477). It may

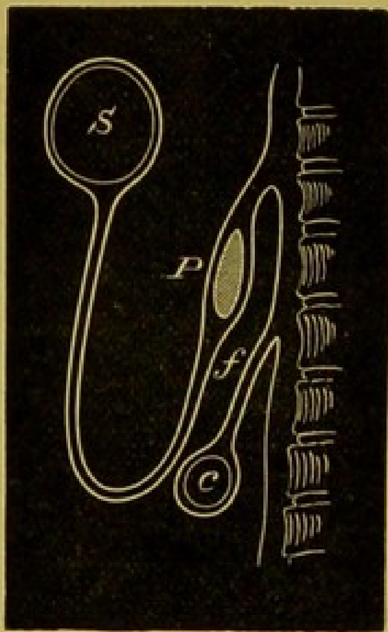
Diagram 4.



S. Stomach fastened to the spine by its mesentery before the latter has become great omentum.

therefore be sufficient to recommence at the point at which their description was discontinued. Beginning with the mesogastrium, perhaps it is remembered that although at first very simple (Diagram 4), yet it afterwards grew and descended from the greater curvature of the stomach to form a loop, the great omentum, and that afterwards it ascended to be fastened to the back of the abdomen. If these ascending layers be traced, the innermost, after reaching the spine, passes upwards to form the back of the lesser sac; the underlayer accompanies it until the spine is reached, and then turns downwards to become continuous with the upper layer of the

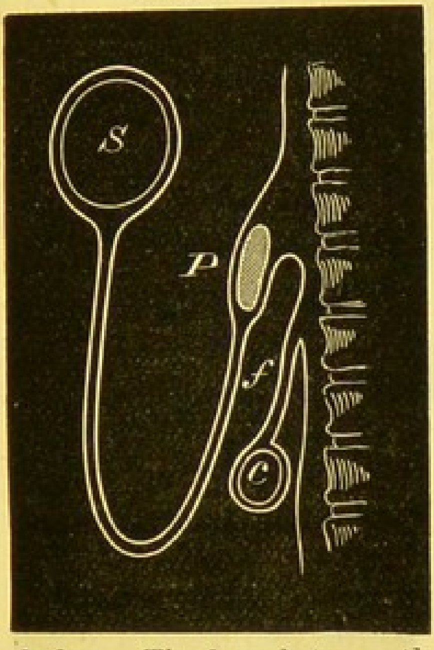
Diagram 5.



S. Stomach. *P*. Pancreas. *f*. Fossa. *c*. Transverse colon.

transverse mesocolon (Diagram 5). Of course it is recognised that at this time the colon has an independent mesentery comparable in every way to that of the small intestine, and it is clear that at this juncture an interval separates the under surface of the omentum from the upper surface of the colon and mesocolon. Now in order to explain how these acquire the intimate relation which they have in the adult, Haller simply stated that they became adherent. This view has been adopted by succeeding authors, and if it is true it must follow, as they say it does, that the transverse mesocolon should consist of four layers of peritoneum, three above the middle colic artery and one below. Although I have examined a great many subjects, the transverse mesocolon has never appeared to consist of more than two layers, one above the artery and one below. If this is true, Haller's theory becomes involved in doubt, even if other objections could not be urged against it. But it seems pertinent to ask why this process of adhesion only occurs in this particular place and

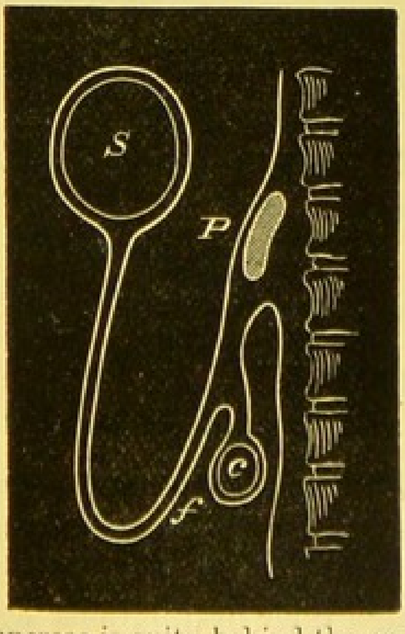
Diagram 6.



The letters are the same as before. The fossa between the omentum and transverse mesocolon is shallower.

nowhere else? Or why, before Haller invented his theory, was the mesocolon always thought to have two layers? The examination of a large number of embryos shows that adhesion never takes place, but that quite a different event happens. Suppose the loop of peritoneum between the under surface of the omentum and the upper surface of the transverse mesocolon was drawn out (see Diagrams 6, 7, and 8, *f*), it would cause the colon to lie between the innermost layer of the omental loop and the inferior layer of the mesocolon; in other words,

Diagram 7.

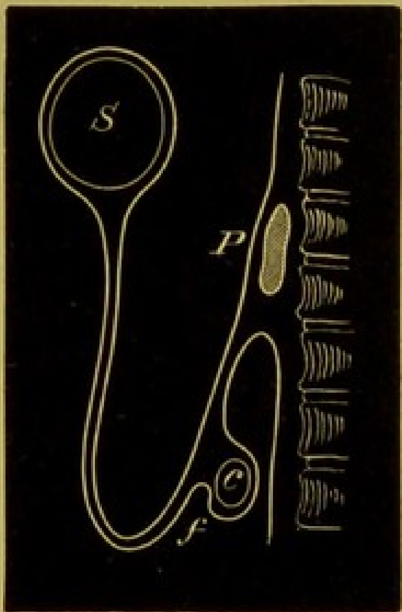


Letters as before. The pancreas is quite behind the peritoneum, the fossa between the mesogastrium and mesocolon having nearly disappeared.

the transverse mesocolon would consist of only two layers, which would embrace the gut and its artery. The paper which has been mentioned was written, and specimens were shown, to demonstrate that this was what took place. If this evidence is true, the usual accounts of the relations of the transverse mesocolon and its contents require to be modified.

It may be remembered that a little while ago it was said that it would be convenient to defer the final stages of the development of the pancreas. When this organ was last spoken of it lay between the folds of the mesogastrium just before this membrane was attached to the spine (Diagram 5). In consequence, the fossa between the meso-

DIAGRAM 8.



The letters as before. To show the last stage in the disappearance of the fossa between the omentum and transverse mesocolon.

gastrium and the mesentery of the transverse colon intervened between it and the spine. It is clear that if the highest part of the peritoneal loop which forms this fossa was withdrawn, the pancreas would naturally apply itself to the spine (Diagrams 6 and 7). That this is what occurs need not be repeated, and as the under surface of the mesogastrium is continuous with the left surface of the mesoduodenum, the drawing out of the one causes the disappearance of the other.

All the arteries of the alimentary canal from the stomach to the rectum have now been discussed, and I have maintained that—

First. All of them, even the splenic and hepatic, were originally derived from the dorsal aorta for the supply of the mid-gut.

Second. That they reach their destinations by passing through the mesentery.

Third. That they participate in all the changes the mesentery undergoes.

Fourth. That if an organ is developed in the mesentery or from the gut, it obtains, part at least, of its vascular supply from the vessels of the mesentery, or from those of that part of the gut from which it sprung.

These principles have, in this paper, only been applied to the development of the blood-vessels of the human alimentary canal, but they seem so simple, and the probability of their truth appears so great, that it may be anticipated that they will be found of very much wider application.

HARRISON AND SONS, PRINTERS IN ORDINARY TO HER MAJESTY, ST. MARTIN'S LANE.