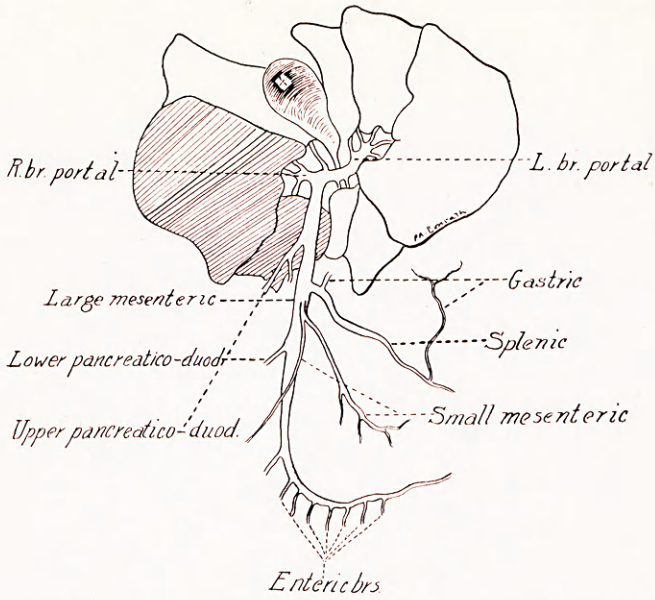

FIG. 1.—Diagram of the portal system of the dog. The distribution of the right division of the portal vein is indicated by linear shading.

FIG. 2.—Radiogram of dog's liver after intraportal injection of iodised oil. Note the absence of large sized intralobar anastomoses. The shadow of the gall-bladder is clearly depicted, and fine venules are seen on its surface.

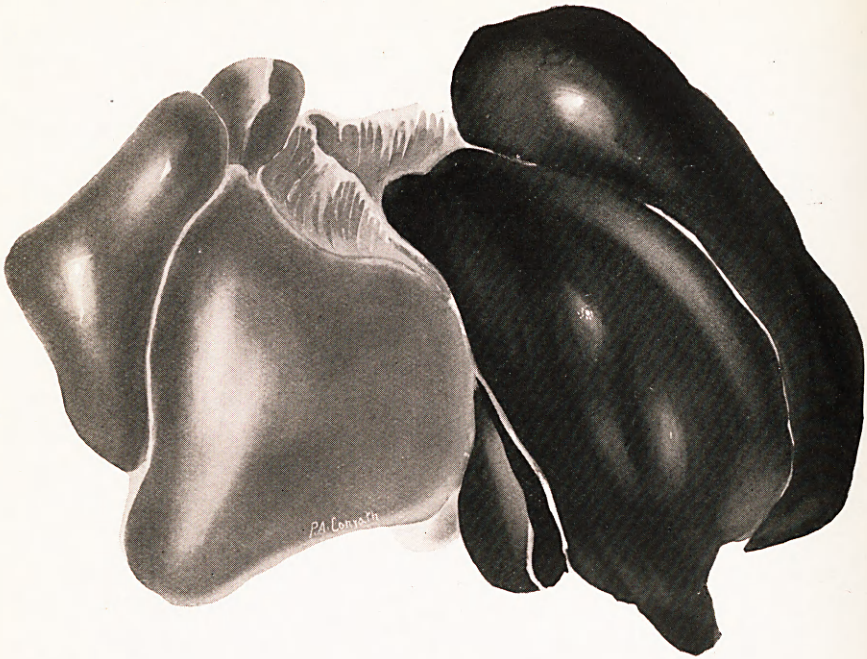

FIG. 3.—Appearance of dog's liver after injection of trypan blue into one of the gastric branches of the splenic vein. Note the complete absence of staining of the right half of the liver.

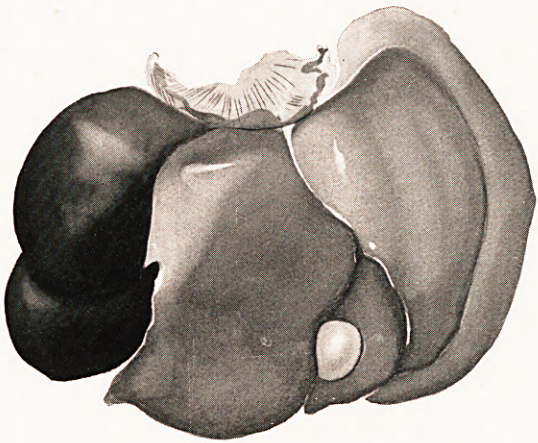

FIG. 4.—Appearance of dog's liver after injection of trypan blue into the upper pancreaticoduodenal vein. Injection of the jejunal veins produces a similar distribution of dye in the liver.

"STREAM-LINES" IN THE PORTAL VEIN: THEIR INFLUENCE ON THE SELECTIVE DISTRIBUTION OF BLOOD IN THE LIVER.*

By BRUCE M. DICK, M.B., F.R.C.S. ED.

By the celloidin-corrosion method M'Indoe[1] and Counsellor (1927) demonstrated that, in the human liver, the area of distribution of the right and left branches of the portal vein is sharply divided in a plane from the fossa for the gall-bladder to the inferior vena cava, and that the only communication between the two sides is by intercellular sinusoids. The same line of demarcation separates the field of supply of the branches of the right and the left hepatic artery and also the drainage area of the two hepatic ducts. The plane of lobar separation, as revealed by celloidin injections, corresponds to the recognised embryological boundary between the right and left halves of the liver. The demonstration of anatomical bilaterality of the liver afforded by the above method confirms the earlier observations of Cantlie,[2] Sérégé,[3] Looten,[4] and others.

Corresponding to the anatomical division of the liver into two separate units it has been suggested that there may be functional differences between the two lobes. A few observations have been made that partly substantiate this hypothesis. Sérégé[5] (1902) found well-marked differences in the urea content of the right and left lobes of the dog's liver in the various phases of digestion after a diet of chopped meat. Loeb[6] (1907) found that the iodine content of the right lobe of the rabbit's liver was constantly greater than that of the left, one hour after subcutaneous injection of potassium iodide. Wells[7] and Hedenburg (1912) confirmed this finding.

A few experimental and clinical studies have suggested the possible occurrence of a selective distribution of portal blood in the liver, and the presence of independent currents of blood in the portal vein. The evidence in favour of the existence of these phenomena does not seem to have been generally known or seemingly accepted.

Glénard[8] (1890), from a series of clinical observations, postulated that well-marked alterations in size, consistency,

*The experimental work connected with this article was carried out in collaboration with Glover H. Copher, M.D., in the Washington University School of Medicine and Barnes Hospital, St. Louis.

A more detailed account of the anatomical and technical aspects of the subject appeared in the Archives of Surgery, July 1928.

and tenderness occurred in the lower palpable border of the liver in many diseases, for example, in diabetes, the right lobe was found to be the seat of most marked change, and, in alcoholic gastritis, the left lobe was most affected. Sérégé (1901) injected India ink into the splenic vein of dogs and found particles only in the left lobe of the liver; when the injection was made into the large mesenteric vein particles were found only in the right lobe. Glénard[9] (1901) repeated these experiments with identical results. However, Bauer[10] (1910), Gilbert and Villaret, and others were unable to distinguish any difference in the distribution of the ink after injections into the splenic and mesenteric veins and therefore discredited the hypothesis of Sérégé and Glénard that a dual current existed in the portal vein. Bartlett,[11] Corper, and Long (1914) examined microscopic sections of the lobes of the dog's liver after injection of olive oil into tributaries of the portal vein. From the unequal distribution of fat-emboli in the liver they concluded that a dual current existed in the portal vein and that blood from the stomach, spleen, duodenum, and first part of the jejunum and rectum flowed mainly to the left lobe, while blood from the lower jejunum, ileum, and first portion of the large intestine flowed mainly to the right lobe.

In our investigations a study was made of the blood currents in the portal vein itself, and the subsequent distribution of the blood in the liver was observed. The experiments were performed on dogs under ether anæsthesia.

Method Employed.—Trypan blue, dissolved in blood-serum, was injected into different radicles of the portal vein and its subsequent localisation in the liver was observed. The advantages of the dye are its lightness and solubility and the parts of the liver to which it is conveyed by the blood-stream are immediately coloured. The staining of the liver persists for some time and formalin preservation of the specimens does not discharge the colour. The method overcomes the objections to the use of particulate matter for intravenous injection.

To identify and study the currents in the portal vein a powerful electric light was placed behind the vessel; in this way, satisfactory transillumination of the moving blood-current was obtained. The experiments were conducted in a dark room, and the transilluminated portal vein was kept under observation while trypan blue was injected slowly into its various tributaries.

Dissections were made to ascertain the position and relations of the more important tributaries of the portal vein. Particular note was made of the angle at which the tributaries joined the main portal channel (Fig. 1).

The intrahepatic course of the portal vein was studied in radiograms of the excised liver after intraportal injections of iodised oil (figure 2).

The accompanying illustrations indicate the salient features of the portal system of the dog and render detailed anatomical description unnecessary.

Results of Experiments—A. *Selective Distribution of Portal Blood in the Liver.*—The site of injection of the dye and the part of the liver to which it was conveyed by the portal blood-stream are summarised in the following table.

Site of Intraportal Injection.	Part of Liver to which Dye was carried.
Splenic vein . . .	Almost the whole of left half of the liver was coloured by dye. A limited area of the upper part of the extreme right lobe of the liver constantly received a portion of dye. Rest of liver retained its normal chestnut colour.
Gastric vein, near lesser curvature.	Whole of left half of liver was uniformly stained by the dye. Line of separation between right and left halves was sharply demarcated and thrown into striking contrast by the unilateral staining of the liver (figure 3).
Upper pancreaticoduodenal vein. (Drains most of head of pancreas and upper part or duodenum)	Dye constantly carried to right side of liver. The two lobes on the extreme right of liver were most deeply stained. A very small amount was deposited in the right border of that lobe which adjoins the two most lateral lobes (figure 4).
Lower pancreaticoduodenal vein.	Dye carried mainly to right half of liver. Certain amount reached left side. Lobe immediately to right of gall-bladder always showed deeper staining than any other part of liver.
Upper jejunal veins . .	Bulk of dye registered itself in two extreme right lobes of liver. Occasionally, scattered spots of colouration found in left half of liver. (Figure 4 indicates average appearance)
*Vein in meso-appendix .	Dye transported to all parts of liver. Large outer left lobe of liver generally showed greater deposition of dye than other parts. In some dogs the right half of the liver showed greater amount of dye than left (*vide infra*).
*Vein in mesentery of descending colon . .	Dye distributed throughout liver. Greater amount was always evident in the left side, more especially in the large lobe on the extreme left.
Large mesenteric vein .	Dye deposited in two lobes at extreme right of liver. Little carried to lobes of left side.

* In many dogs the right and left branches of the small mesenteric vein do not unite in a single trunk but enter the large mesenteric vein separately. When the vessels had a separate termination it was found that injection of dye into the right vein resulted in a more liberal distribution of dye in the right side of the liver.

The strength of trypan blue employed was one gramme in fifteen cubic centimetres of blood-serum; three cubic centimetres was the amount generally given at each injection. About a hundred experiments were performed.

Changes of posture of the animal on the operating table while an injection was made did not alter the mode of distribution of the dye.

When the dye had registered itself in a particular area of the liver there was only a very slight tendency for diffusion to occur to a part beyond the initial site of localisation. After about ten minutes the dye commenced to disappear from that part of the liver in which it had at first deposited itself and the liver as a whole assumed a slightly darker colour, but only to the same degree as the organs of the body that, for a time, became tinted a light blue colour when the dye reached the systemic circulation.

When a large volume of dye was injected the liver was stained throughout, but the staining was not equal in all parts, for instance, if a large amount of dye was introduced into the splenic vein the whole liver assumed a blue colour, but the staining was always much more pronounced in the left side.

B. *Visualisation of the Currents within the Portal Vein.*—When the portal vein was transilluminated the rapidly moving blood-current was at once visible. The discharge of blood from the larger tributaries into the main channel could be seen plainly.

Trypan blue was introduced slowly into different branches of the portal vein, and the transilluminated vessel was meanwhile kept under observation. A very striking demonstration of sharply segregated intraportal currents was afforded.

When the splenic vein was injected the dye-stained blood was seen to enter the left side of the portal vein. The dye-stained stream kept strictly to the left side of the portal vein and preserved a narrow ribbon-like course throughout the entire length of the portal vein. No mixing with the blood in the adjacent broad mesenteric stream was noticed.

When one of the jejunal veins was injected with a dye a narrow, abruptly demarcated stream was observed; it maintained a constant undeviated course along the right wall of the portal vein. No mixing with "red" blood was seen to occur as the stream was propagated to the hilum of the liver.

Injection of branches of the small mesenteric vein enabled

a thin linear current of blood to be visualised in the centre of the portal vein towards its ventral aspect. The current preserved a clear-cut linear course throughout the portal vein and no diffusion with adjacent blood was detected.

Discussion and Conclusions. — Anatomical studies have proved conclusively that the human liver should not be regarded as a single compact organ, but as one made of two units that possess an independent blood supply and an entirely separate biliary drainage system. There is no proof that the two halves of the liver have a different function, although a few experimental studies lend a little colour to this belief.

We have found by the injection of trypan blue into tributaries of the portal vein of dogs that, with a few exceptions, the dye is carried in the blood-stream to fairly constant and definite areas in the liver. It was found that when the dye was injected into the splenic and gastric veins it was conveyed to the left half of the liver almost entirely. Dye introduced into the veins of the upper duodenum, head of the pancreas, and the jejunum was carried almost exclusively to the two right lateral lobes of the liver. When the colonic veins were injected the dye was distributed to all parts of the liver but more particularly to the large lobe of the left side. In the instances in which the colonic veins did not form a common trunk, but had a separate termination in the large mesentric vein, it was found that injection of the veins of the proximal colon produced a freer distribution of dye in the right half of the liver.

When dye is conveyed to a particular portion of the liver the staining remains sharply circumscribed. The absence of diffusion to other parts of the liver is explained by the terminal character of the larger divisions of the portal vein. Temporary staining of the liver does not signify that the blood that conveyed the dye has remained confined in a demarcated area of the liver, as, after intraportal injection, the dye is almost immediately recognisable in the general circulation, and, furthermore, the mass-movement of blood from the liver is very large and rapid.

A reasonable inference from the above observations is that blood that has been conveyed from the periphery of the portal circulation to a particular section of the liver is probably utilised in that specific area without contact with blood from other parts of the portal tree. It is of interest to note that, in our observations, blood that is carried to the left lobes of

the liver is drained principally from the abdominal viscera that are not strictly engaged with digestion or absorption of food, namely, the spleen, stomach, and greater part of the colon. Whereas, blood, drained from those parts of the alimentary tract in which products of digestion are absorbed, is conveyed to the right side of the liver. In brief, it would seem from our evidence that there are areas in the liver, that are supplied with blood from specific parts of the portal system, and that blood from different parts of the portal system does not become mixed in the liver, nor, as is indicated below, in the portal vein itself.

An explanation of the selective distribution of portal blood in the liver is afforded by the visual demonstration of "stream-lines" in the portal vein. These currents seem to be designed for the conduction of blood from the periphery of the portal tree to the liver in such a manner that little or no intermingling of the individual streams occurs in the main portal channel. There appear to be at least three main blood-currents in the portal vein. They are initiated and maintained by the blood-flow from the splenic, large mesenteric, and small mesenteric veins. These veins are the largest contributors of blood to the portal vein of the dog. Their anatomical disposition would seem to be favourably adapted to the ejection of blood into the portal vein in such a direction that the individual streams could remain separate. These anatomical advantages are probably further aided by known differences in the rate of blood-flow in the veins, differences in viscosity of the blood they contain, and variations in tonicity of the vessel walls.

Maintenance of individuality of different currents in the portal vein finds a counterpart in the familiar observation that two rivers, one muddy and the other clear, often retain their identity for a considerable distance after union in a common stream bed. This phenomenon of separate streams in a moving body of water is well known to hydraulic engineers and is usually discussed under the name of "stream-lines."

Summary.—Experimental evidence is presented which indicates that, in the dog, individual lobes of the liver receive portal blood from different visceral sources.

By transillumination of the portal vein and injection of a dye, segregated streams of blood have been recognised in the portal vein. There are probably three main streams, viz., the splenic, large mesenteric, and small mesenteric. These intra-

vascular currents have been named portal "stream-lines." The selective distribution of venous blood in the liver is probably determined by these intraportal currents.

The previous anatomical and experimental investigations that pertain to the subject of selective distribution of blood in the liver have been reviewed briefly.

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