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Anatomy of the Hepatic Vascular System of the Eel, *A. japonica*

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Abstract

Morphological study was performed to investigate distributions of the afferent and efferent vessels as the hepatic artery, hepatic and portal veins, and also of the bile duct system in the eel, *A. japonica*. As for the hepatic and portal veins, their branching patterns were observed after cutting open their vessel walls. For the bile duct, its connection between the hepatic duct and duodenum was traced. For reference, the marbled eel, *A. marmorata*, was used especially to recognize its detailed relation of branches of the coeliac artery. Each restoraion was done conerning with above mentioned vascular system by drawing its external feature. As results, branching number of the right side of the hepatic vein is less than that of the left side and the same or approximate as in the portal vein. Divided typed branches which go towards the left lobe of the liver after deriving from the portal vein pass below the hepatic vein. Their number is approximately same as that of the right branches of the hepatic vein. Hepatic artery derives from the coeliac artery. It sends mono- or divided typed branches to the anterior hepatic parenchyma on its way and later penetrates into the latter. The other routes to the liver are recognized as two branches of the gastric artery which derives from the coeliac artery. They distribute on the posterior parenchyma of the liver. Bile duct is composed of the hepatic and choledochal ducts, the former sends out two to four branches to the parenchyma and connects itself to the latter. The latter opens to the duodenum, being enveloped in the ODDI's sphincter. The gall bladder connects through the cystic duct with the hepatic duct.

From old time in Japan, the eel has been an important source as a natural product of animal protein. According to an abrupt increase of demand as merchandise, its cultivation has been spread recently with high technical devices as the intensive and forcing cultures and then its demand-supply balance now equilibrates in the first place. However on its cultivation field, new diseases of eels which are considered to be due to an unnatural and insanitary habitat take place and disappear successively. Such a recent tendency occurs widely as it were in parallel to the production increase. Well, its remedy or prevention of epidemics has been temporizing and forestalled as matters now stand. One of its reasons seems that the eel as a direct object hasn't been hitherto well studied scientifically. Especially its useful morphological and physiological data seem to be insufficient. In this report, from the above mentioned point of view a morphological approach has been performed concerning with the important internal organ as liver of the eel. Work adjusted the focus on its vascular system as the hepatic artery, hepatic vein and portal vein. Observing their distribution on the liver and each sending pattern of their

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branches into the latter, some drawings were performed accompanying with recognition of a bile duct system.

Materials and Method

Eels, *Anguilla japonica,* used in this study were 40-50 cm in body length and all brought by a culturist. For reference, a marbled (giant long-finned) eel, *A. marmorata,* of which body length was 110 cm was used especially for recognition of detailed connections of branches of the coeliac artery at the region superior to the duodenum, which had been obtained at the Ikeda Lake of Kagoshima Prefecture and stocked in 10% formalin for a long time at the laboratory. Eels were dissected after fixation of 10% formalin. Internal organs as the liver, pancreas, spleen, stomach and related vascular ducts were extirpated taking care of their intact connections. As for afferent vessels of the liver, the hepatic artery was traced to its deriving point on the coeliac artery, and also some other arteries deriving from a branch of the latter were investigated besides the portal vein. Hepatic vein which was partly buried in the parenchyma was restored to its original state from the results of sectional observations. Each restoration was also done concerning above mentioned vessels and the bile duct system for the purpose of understanding their mutual relations or branching patterns. All the experiments were performed under binocular or naked eye, using properly a weak solution of methylene blue.

Results and Discussion

Liver is situated adjacent to the pericardial-abdominal cavity membrane, enclosing dorsally the oesophagus, stomach and an anterior part of intestine. Its left lobe is larger than the other side, attaining to the cardiac orifice. Right lobe is provided dorso-posteriorly with the gall bladder which shows a oval shape. For this organ, such afferent vessels as the hepatic artery and portal vein, and an efferent vessel as the hepatic vein are distributed as follows.

1) Hepatic vein (**Fig. 1** and **2**)

Being buried partly in the dorsal parenchyma a little to the left lobe, inferior to entirely raised trunk of portal vein, the hepatic vein runs through a connective tissue which is surrounded by a fibrous tunic in parallel to the liver axis. At the anterior area of the liver, it alters its position in a midline, then, connects with the venous sinus. Previous tunic is named as the GLISSON's tunic being composed of a connective tissue and elastic fibers, and sinks deeply forming the vessel vagina into the parenchyma at the head liver. Trunk section of the hepatic vein shows a roundish rhombic shape, partly long ellipsoids at branching levels having the line of apsides along the branching direction. Its diameter changes along its axis, that is, the most swelled portion is on this side of the sinus junction and it gradually decreases towards the other end. Near by the gall bladder, it curves leniently to the left side. Diameter of the joint part to the sinus becomes to be immediately slender. Its structure seems reasonable to get a suitable blood pressure when it

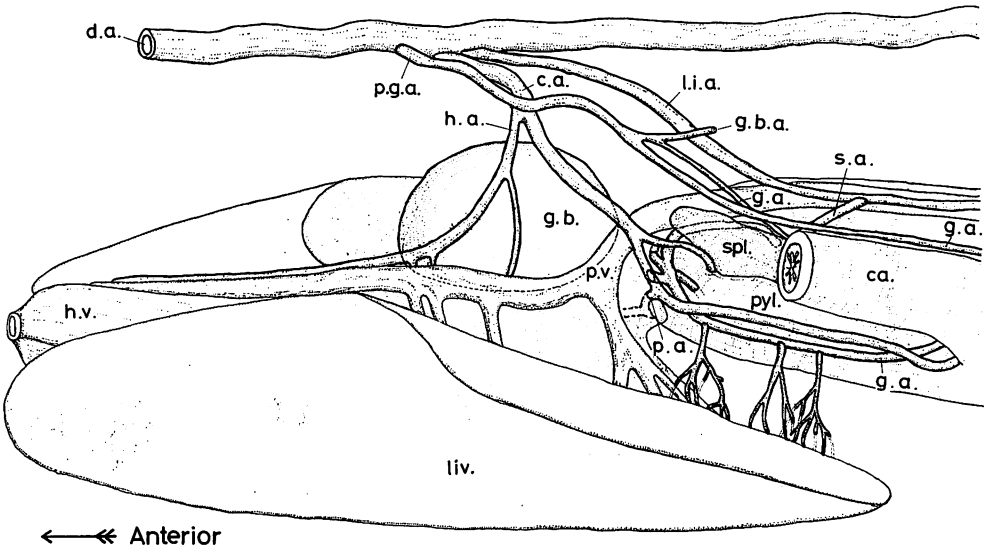


Fig.1. Diagrammatic drawing of the vascular relations at the hepatic area of the eel (left-laterally viewed). Dorsal aorta sends out three arteries as the coeliac, lieno-intestinal and pneumogastric. Liver receives afferent blood from the hepatic artery, some branches of gastric artery and portal vein. Abbrev., ca. : cardiac orifice, c.a. : coeliac artery, d.a. : dorsal aorta, g.a. : gastric artery, g.b. : gall bladder, g.b.a. : gas bladder artery, h.a. : hepatic artery, h.v. : hepatic vein, l.i.a. : lieno-intestinal artery, liv. : liver, p.a. : pancreas artery, p.g.a. : pneumogastric artery, p.v. : portal vein, pyl. : pylorus, s.a. : spleen artery, spl. : spleen.

goes out into the sinus. In fishes, the opening of the venous sinus for the entrance of hepatic blood is generally counted as a pair, but in the eel its number is non-paired one. Branches which collect on the hepatic vein show a numerical difference between the left lateral and right one. As for the former, branches form a line along the midline of lateral wall. All of their diameters are comparatively large (more than 0.5 mm), accompanying by dispersed less sized branches (0.1-0.2 mm) which are supplementary. At the posterior portion, especially, such small branches are distributed widely. On the contrary, the dorsal side of anterior swelled portion just before the sinus junction shows almost no distribution of branches. Its reason is that this area is a raising state apart from the parenchyma. In addition, there exists always one branch at the ventro-lateral or mid-lateral of this area. Such an existence is also observed for the right side of the hepatic vein. As for the right side, slightly larger branches than in the left side have a diverge type as two or three and their number is the same or approximate as the branching number of portal vein of which branches run in parallel to the right branches of hepatic vein. Its number is far a few compared with that of the left side. It may be because of the constructional situation, that is, the right lobe bears the portal branches, gall bladder and its related ducts. All branches of both sides show to penetrate forwards at an oblique angle to the parenchyma.

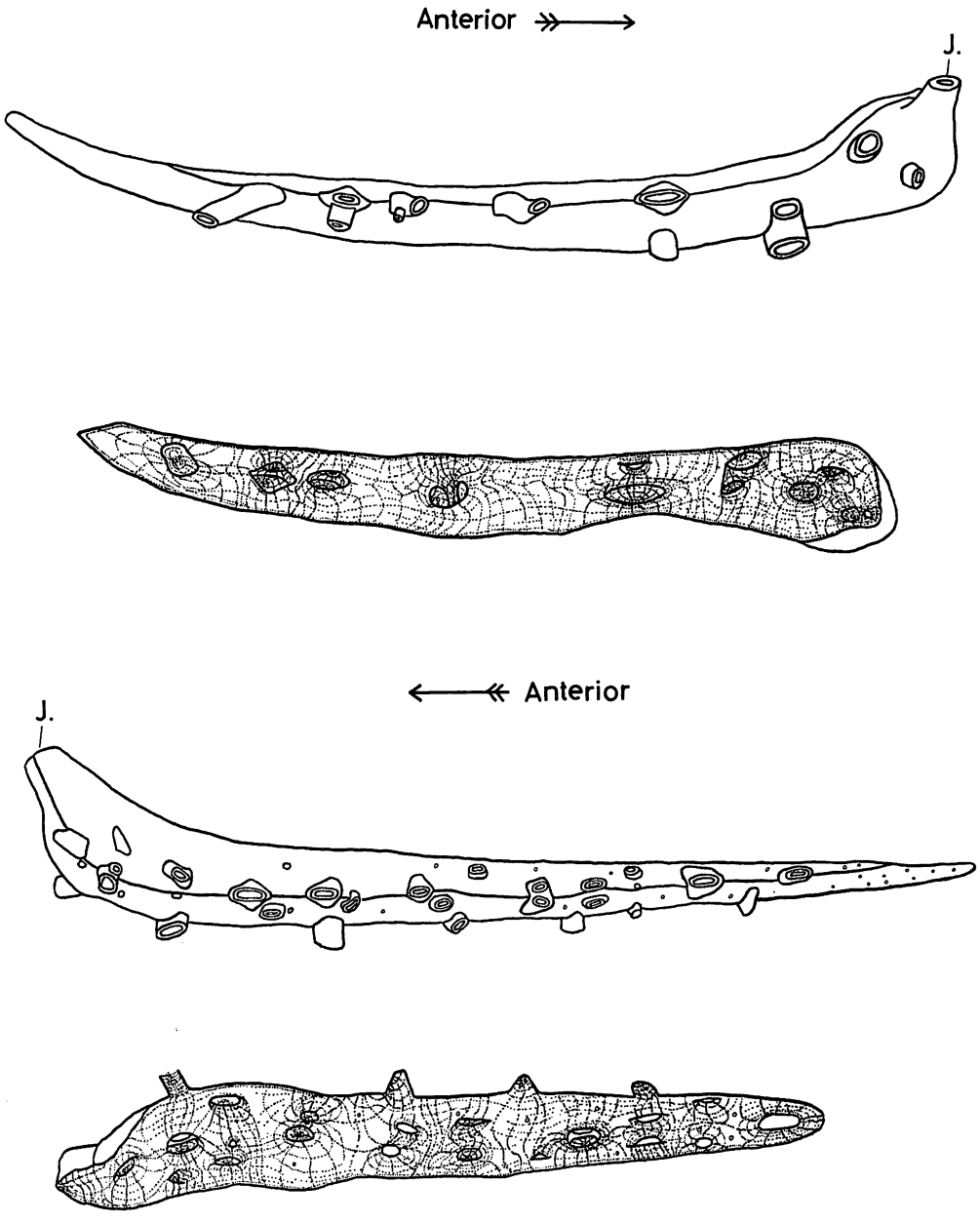
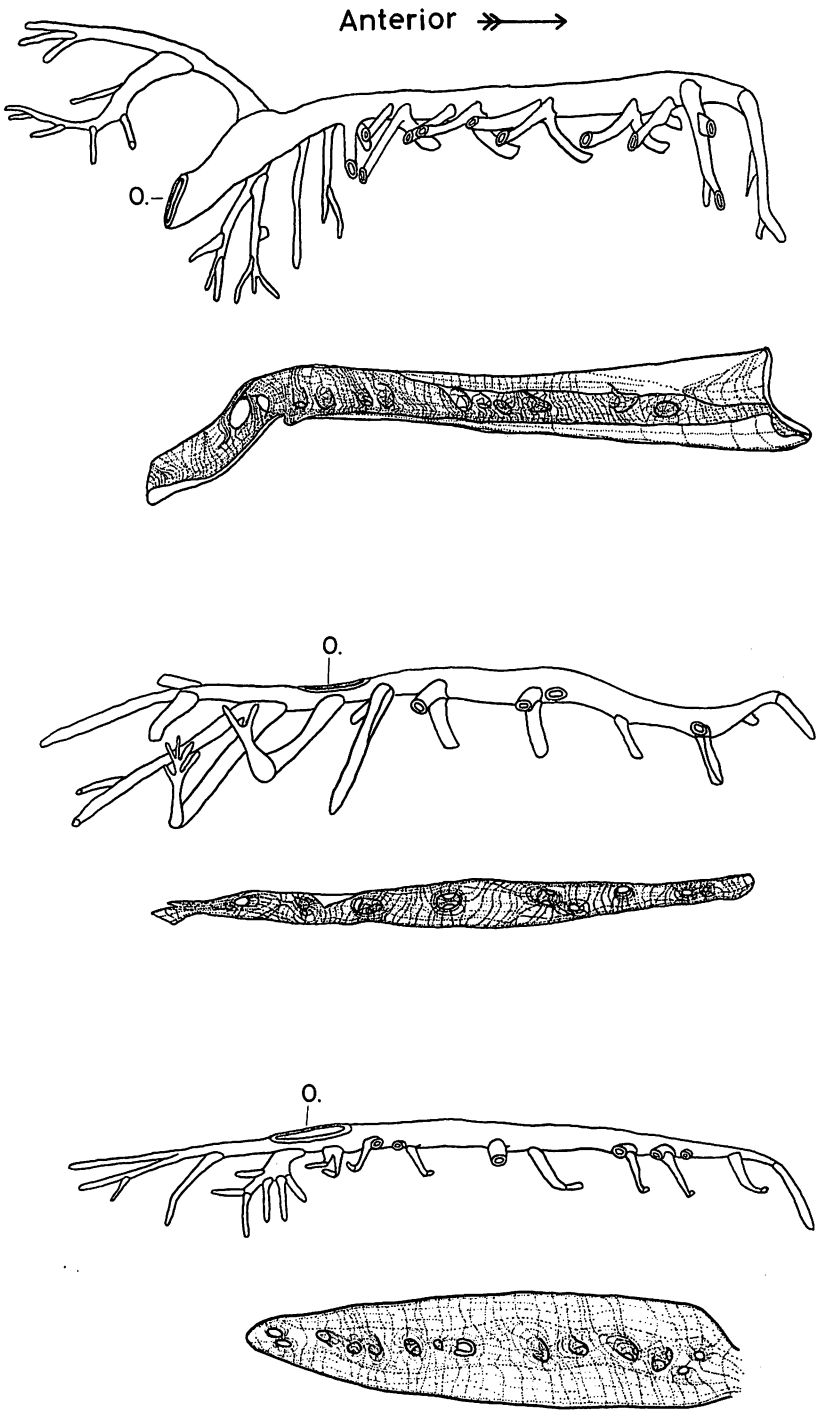


Fig. 2. Diagrams of the external and internal features of a hepatic vein, observed each right (upper) and left (lower) branching pattern. Capital **J.** in the figure shows a joint part of the venous sinus.


Anterior
O.
O.
O.

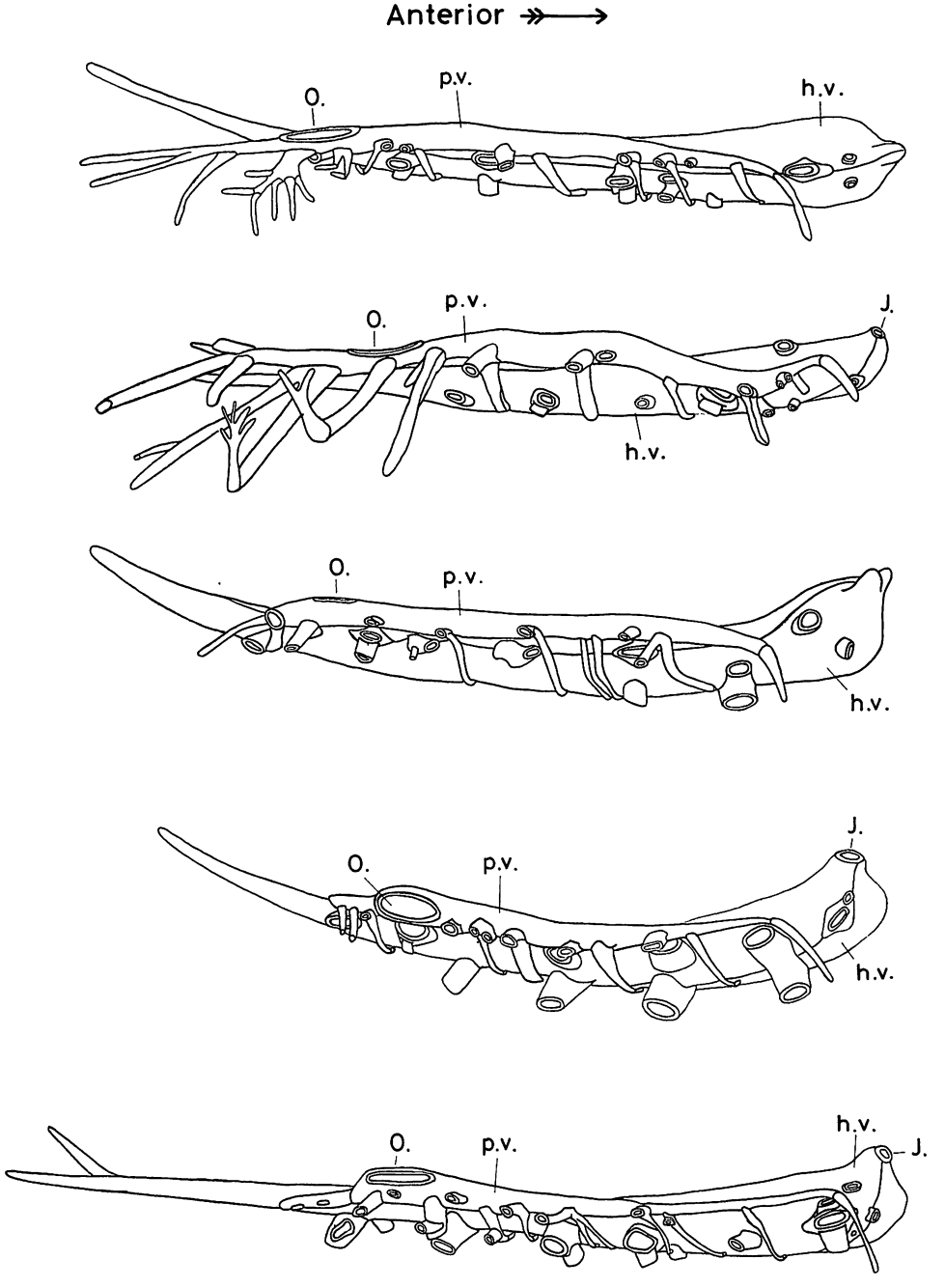
2) Portal vein (**Fig. 1, 3** and **4**)

Portal vein coming from the intestinal region divides itself near the gall bladder into the anterior and posterior boughs. Both go to each partial charged parenchyma of liver. This portion of diverging point shows the largest diameter, then, gradually decreases its value along bough's axes, respectively, sending out some secondary branches. Anterior bough goes raising state on a midline of the dorsal plane of the liver along the hepatic vein and bile duct, sending out seven to nine branches to the parenchyma. The first branch is at the middle level of the gall bladder, the second and third are situated having a narrow interval at the front level of the latter. These branches raising themselves on the dorsal surface of the liver go towards the left lobe, and penetrate to the parenchyma after passing through just below the ventral of the hepatic vein and further diverging into two or three. However, such branches show non-raising state after deriving from the trunk in some cases. It seems therefore the above mentioned pattern has individual variations. Anterior end of the portal vein changes its position on a midline and alters its direction suddenly towards the ventral of the right lobe, decreasing its diameter less than that of the branch of the hepatic vein. Posterior bough diverges again into three branches after its initial separation. Each branch penetrates into the posterior parenchyma of the left lobe. All branches of both boughs penetrate forwards at an oblique angle to the parenchyma like as of the hepatic vein. Peripheral branches which are distributed in the left lobe show the same or approximate number as right branches of the hepatic vein. However, such small branches (0.1-0.2 mm) as observed in the hepatic vein are not recognized in the portal vein.

3) Hepatic artery (**Fig. 1, 5** and **6**)

Hepatic artery derives from the coeliac artery superior to the gall bladder. The coeliac artery derives from the dorsal aorta which runs along the body axis under the vertebral column. The latter sends out further two arteries vertically as the lieno-intestinal and pneumogastric at almost same position as the coeliac artery, that is, superior area to the gall bladder and between the oesophagus and left side of the gall bladder. According to MOTT[1], the lieno-intestinal artery runs along the dorsal of the portal vein, and later sends out one branch to the spleen. The pneumogastric artery has three main branches; one of them goes to the trachea and red gland, another goes to the posterior of the spleen and also to the ventral side of the anterior intestine, the remnant sends branches to the pylorus and oesophagus. The coeliac artery divides into two branches as the hepatic and gastric, the latter branch runs along the inner wall of the pylorus or its other branch goes to the mesentery distributed on the intestine. In this experiment, as for the lieno-intestinal and pneumogastric arteries same results were obtained. The former artery runs backwards along the left superior area to the gall bladder, after deriving from the most posterior point on the dorsal aorta among the three deriving arteries. Going along the dorsal of the portal vein at the intestinal region, it sends out the spleen artery as a branch of the intestinal artery

Fig. 3. Diagrams of three portal veins, each showing its external and internal features of branching pattern right-laterally. Capital **O.** in the figure indicates the opening caused by separation itself from the proximal trunk at this level.


Anterior
O.
p.v.
h.v.
O.
p.v.
J.
h.v.
O.
p.v.
h.v.
J.
O.
p.v.
h.v.
h.v.
O.
p.v.
J.

which advances backwards. The latter artery derives from the most anterior point on the dorsal aorta among the three deriving arteries, and after that it sends out four main branches. One of them attains to the red gland as the swim-bladder artery. Another as the gastric artery goes along the pylorus to the left side wall of the posterior bending portion of stomach distributing many fine vessels, and further distributes its branches on the mesentery connecting the stomach with the right side of intestine. The remnant named as the gastric artery which is a branch of the swim-bladder artery runs along the intestine or left side of the portal vein at the intestinal area to the right side wall of the posterior bending portion of stomach, and distributes many fine vessels there and the mesentery connecting the stomach with the left side of intestine. However, the vessel which curves towards the spleen and also distributes itself on the antero-ventral of the intestine is not recognized in this experiment. Well, the coeliac artery supported by a fibrous tissue on the surface of the gall bladder divides into two branches at the area of the latter. One of them goes forwards along the portal vein superior to the liver, sending out three to five non-diverged branches near the gall bladder and further at least more than five branches of a divided type to the inferior parenchyma, respectively. This is named as the hepatic artery. According to MOTT[1], this is named as hepatic branch (es). The other of them goes backwards along the left wall of the gall bladder, then, diverges into three branches at the pylorus. One branch curves along the pylorus wall and attains to the mesentery between the pylorus and intestine after passing below the ventral of the spleen. It sends out two or three branches to the pylorus on its way. Another branch named as the gastric artery goes along the dorsal wall of the pylorus to the lateral wall of the bending portion of stomach after sending out at least three branches to the posterior of the left lobe near by the posterior bough of the portal vein. Each branch to the liver is slender enveloped in membranous tissue and its periphery shows a tree-like divergence. The remnant is named as the pancreas artery which derives from the curved portion of the previous gastric artery at the pylorus wall. Passing by the ventral wall of the pylorus, it goes to the pancreas after separating the other artery which attains to the liver. As above mentioned, arterial supply to the liver is performed by three routes as the hepatic artery and two branches of the gastric artery on its way to the bending portion of stomach or to the pancreas.

4) Bile duct (**Fig.7** and **8**)

Bile duct which is composed of the hepatic duct buried in the connective tissue being enveloped in the fibrous tunic and choledochal duct which is named to the connection duct between the joint of the cystic duct and duodenum runs along the dorsal area of the right lobe inferior to the anterior bough of the portal vein. It shows a slender tube-shape and its diameter is less than an one-fourth of the portal diameter. Its size increases in proportion to reaching the gall bladder.

Fig. 4. Some patterns of the positional relationship between the hepatic and portal veins. Portal branches of the right side pass below the trunk of hepatic vein, like enclosing the latter. Abbrev., h.v. : hepatic vein, J. : joint of the venous sinus, O. : opening caused by cutting off its proximal trunk, p.v. : portal vein.

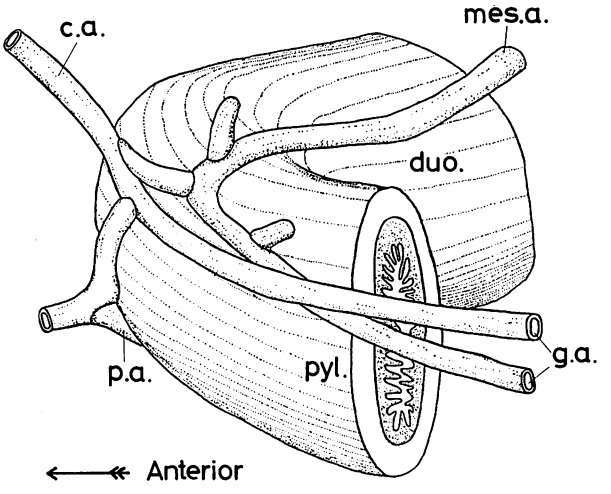


Fig. 5. Vascular relations of such arteries as the gastric, mesentery and pancreas with their trunk of the coeliac artery. Abbrev., c.a. : coeliac artery, duo. : duodenum, g.a. : gastric artery, mes.a. : mesentery artery, p.a. : pancreas artery, pyl. : pylorus.

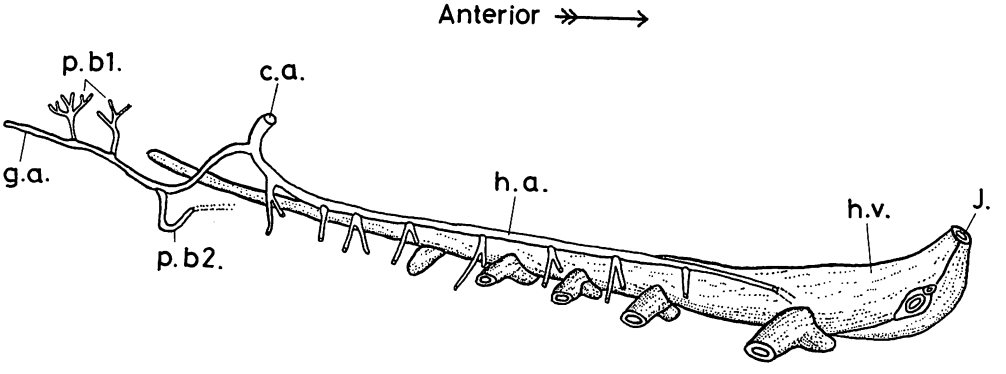


Fig. 6. Distribution of hepatic branches as the anterior and two posterior of the coeliac artery. Anterior branch is named as the hepatic artery. Each of posterior branches derives from the gastric artery. Hepatic vein is added for the comprehension of situational relation. Abbrev., c.a. : coeliac artery, g.a. : gastric artery, h.a. : hepatic artery as anterior bough of the coeliac artery, h.v. : hepatic vein, J. : joint of the venous sinus, p.b1. : posterior branch entering the liver, p.b2. : posterior branch entering the liver.

Hepatic duct sends out two to four branches to the hepatic parenchyma at the middle of the right lobe. It passes below the gall bladder and connects with the choledochal duct. The latter enveloped in the ODDI's sphincter opens to the dorsal lumen of duodenum[2]. The gall bladder and hepatic duct are connected each other with conical shaped cystic duct of which opening to the bladder is as the long elliptical bottom and situated ventrally to the posterior wall of the bladder.

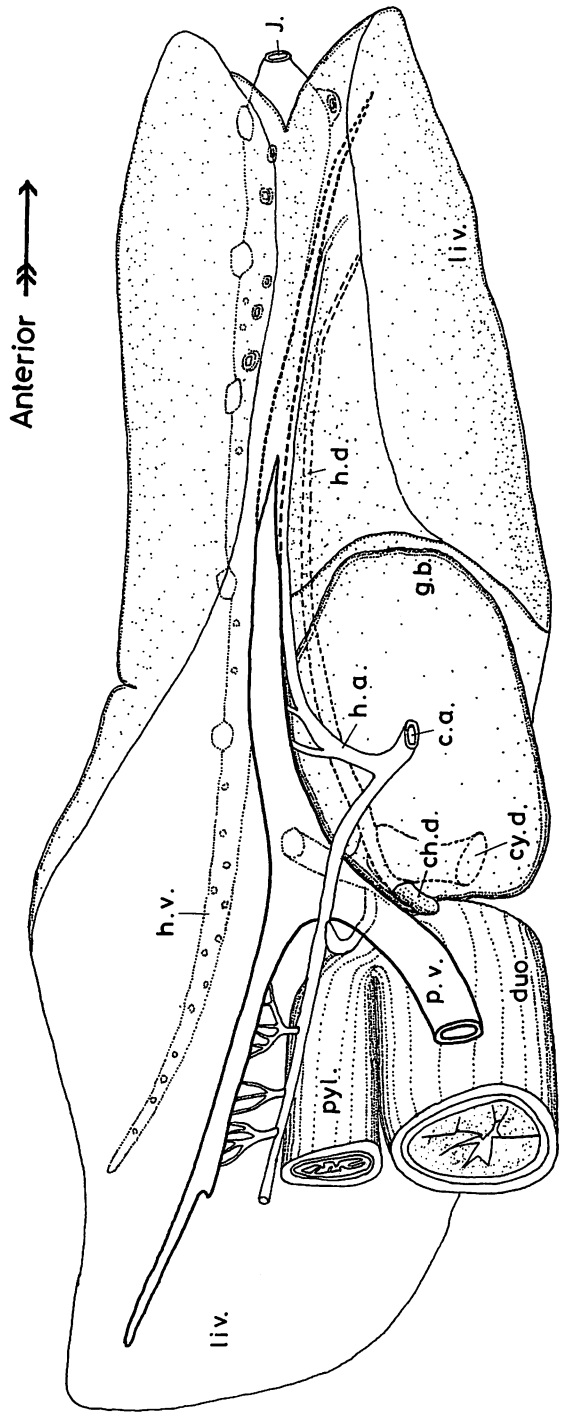


Fig. 7. Diagrammatic arrangement of the vascular and bile duct systems at the superior region of the liver. Abbrev., c.a. : coeliac artery, ch.d. : choledochal duct, cy.d. : cystic duct, duo. : duodenum, g.b. : gall bladder, h.a. : hepatic artery, h.d. : hepatic duct, h.v. : hepatic vein, J. : joint of the venous sinus, liv. : liver, p.v. : portal vein, pyl. : pylorus.

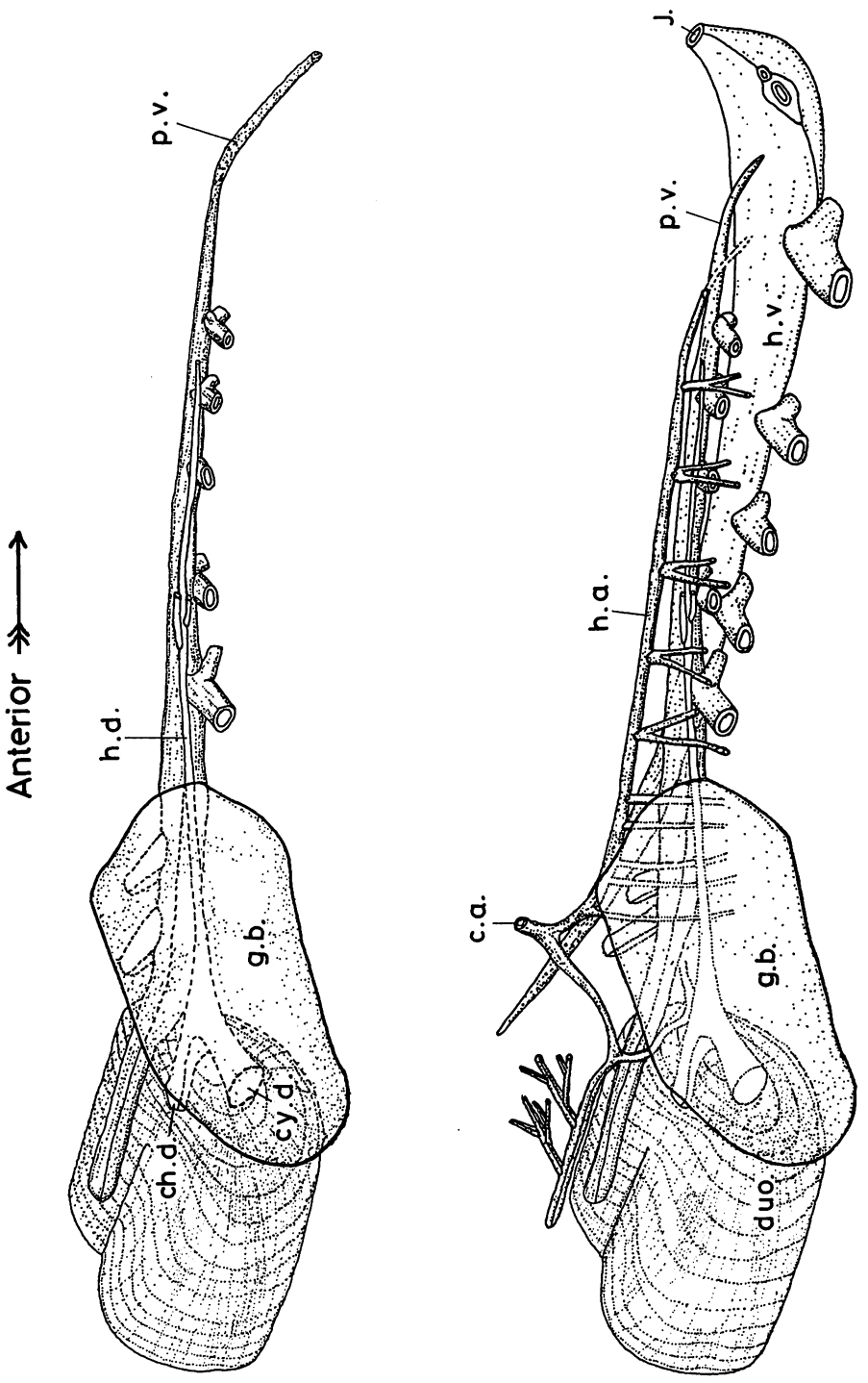


Fig. 8. Bile duct system (upper) and its situational relation with the afferent and efferent vessels to the liver (lower). Abbrev., c.a. : coeliac artery, ch.d. : choledochal duct, cy.d. : cystic duct, duo. : duodenum, g.b. : gall bladder, h.a. : hepatic artery, h.d. : hepatic duct, h.v. : hepatic vein, J. : joint of the venous sinus, p.v. : portal vein.

References

1) MOTT, J. C. (1949): The gross anatomy of the blood vascular system of the eel, *Anguilla anguilla*. *Proc. zool. soc. Lond.*, **120,** 503-518.
2) 松井 魁 (1972) ：消化器系. in "鰻学 (生物学的研究篇)", 恒星社厚生閣, 東京, 135-140.