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SOME NOTES ON THE ANTERIOR DORSAL FIN AND VENOUS DRAINAGE IN *CALLORHINCHUS* (HOLOCEPHALI)

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(with two text-figures and three plates)

SUMMARY

The region of the anterior dorsal fin of the elephant-fish *(Callorhinchus callorhynchus* (L.) has been examined by dissection, by injection of radio-opaque material and in serial sections. Particular attention has been paid to the venous system in the region.

A large venous sinus lies below the basal plate of the fin skeleton and has connections running anteriorly and posteriorly in the midline. Anteriorly, the sinus is connected with the left posterior cardinal vein by a large communicating vein which lies close against the left side of the vertebral column. This arrangement is generally similar to that found in the Selachii, but in the latter group two venae circulares are found instead of the median dorsal sinus of *Callorhinchus* and other Holocephali.

INTRODUCTION

The Holocephali are a small group of shark-like fishes, of which *Chimaera* is the principal representative in the northern hemisphere and *Callorhinchus* in the southern hemisphere. Hobson (1841) gave the first general description of the anatomy of *Callorhinchus*, and only some accounts of particular systems have appeared since (for a bibliography see Stahl 1967). The present notes report a preliminary study of some of the structures associated with the anterior dorsal fin of *Callorhinchus*, in particular the venous channels; and comment upon Hobson's findings.

MATERIAL AND METHODS

Our examination of the anatomy of *Callorhinchus* was limited by the small quantity of material available to us in London. Two small specimens of *C. callorhynchus* (L.) were generously made available to us by Mr. P.J. Whitehead of the British Museum (Natural History) and some others collected in the estuary of the Tamar River, northern Tasmania, were kindly sent to us by Mr. D.C. Wolfe of the fisheries section of the Tasmanian Department of Agriculture.

Nearly all our material was found to be preserved inadequately for histological study and only one series of serial sections of the region of the anterior dorsal fin was reliable. Radio-opaque fluid ('Chromopaque') was injected into the pulpy region at the base of the anterior dorsal fin to study the extent and connections of the venous sinuses in the region by X-ray photography. Several specimens were dissected to study gross morphology.

OBSERVATIONS

The massive anterior dorsal fin lies a short distance behind the head (text-figures 1 and 2). It is roughly triangular in shape and comprises little more than a double layer of skin supported by two layers of "dermal fin rays", and having a prominent and robust spine in its anterior margin. The spine is associated with a basal

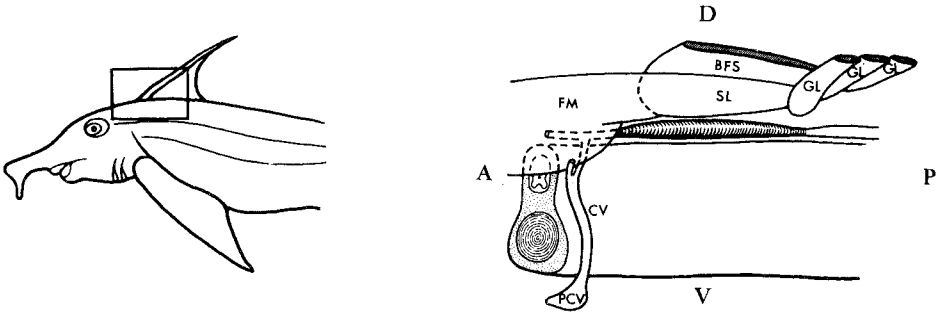

FIG. 1. - (a) Outline sketch of anterior end of *Callorhinchus callorhynchus*. The box indicates the region shown in (b).
(b) Three-dimensional diagram of region of the anterior dorsal fin, from the left side, to show the dorsal venous sinus lying below the basal fin skeleton, and communicating with the posterior cardinal vein.

A: anterior; P: posterior; D: dorsal; V: ventral; and other symbols as for text-figure 2.

skeletal element embedded in the midline between the axial muscles of the two sides. The basal element is connected to the skull and vertebral column by ligaments, and is acted upon by a system of muscles in such a way that the anterior spine (and therefore the fin) can be elevated and depressed. When the fin is depressed the blade folds fanwise, the mass appearing to be accommodated to some extent in a mid-dorsal groove because the tissues underlying the posterior part of the fin are spongy. Details of the structure of the fin skeleton and its musculature were not studied.

In front of the dorsal fin, the midline is occupied on each side by a bundle of muscle which extends from the back of the head to the basal plate of the fin skeleton. These bundles are separated from the axial musculature by an areolar partition, the separation becoming more and more distinct as they approach the basal plate, and they end in a fibrous sling common to the two sides which is attached to the keel of the plate posteriorly. Running longitudinally in the areolar partition is the large dorsal cutaneous vein. Just in front of the basal cartilage of the fin this vein gives off branches on each side which communicate with veins in the fascial partitions separating the bundles from the axial musculature. The two connecting vessels, which run alongside the vertebral arch, differ markedly: that on the left side is large while that on the right is small. Moreover, the left hand vessel continues ventrally beside the basal part of the arch and the body of the vertebra to connect with the left posterior cardinal vein, but on the right side there is no corresponding connection, or at most a very tenuous connection with the right posterior cardinal vein (plate 1). This connecting vessel is known as the profunda vein. Immediately behind it the dorsal cutaneous vein becomes much larger, forming a wide vascular pad separating the fin skeleton and its associated musculature from the vertebral column and the adjacent part of the axial musculature; it may now be called the dorsal fin sinus (Stahl 1967). The areolar tissue separating the dorsal fin and its associated structures from the surrounding tissues changes at this point, now containing many blood vessels and being very loose, so much so that the serial sections show many tears (and artificial spaces) along the fibrous planes.

X-ray studies have shown that when radio-opaque fluid was injected into the areolar tissue at the base of the dorsal fin, it flowed into vessels in the abdomen

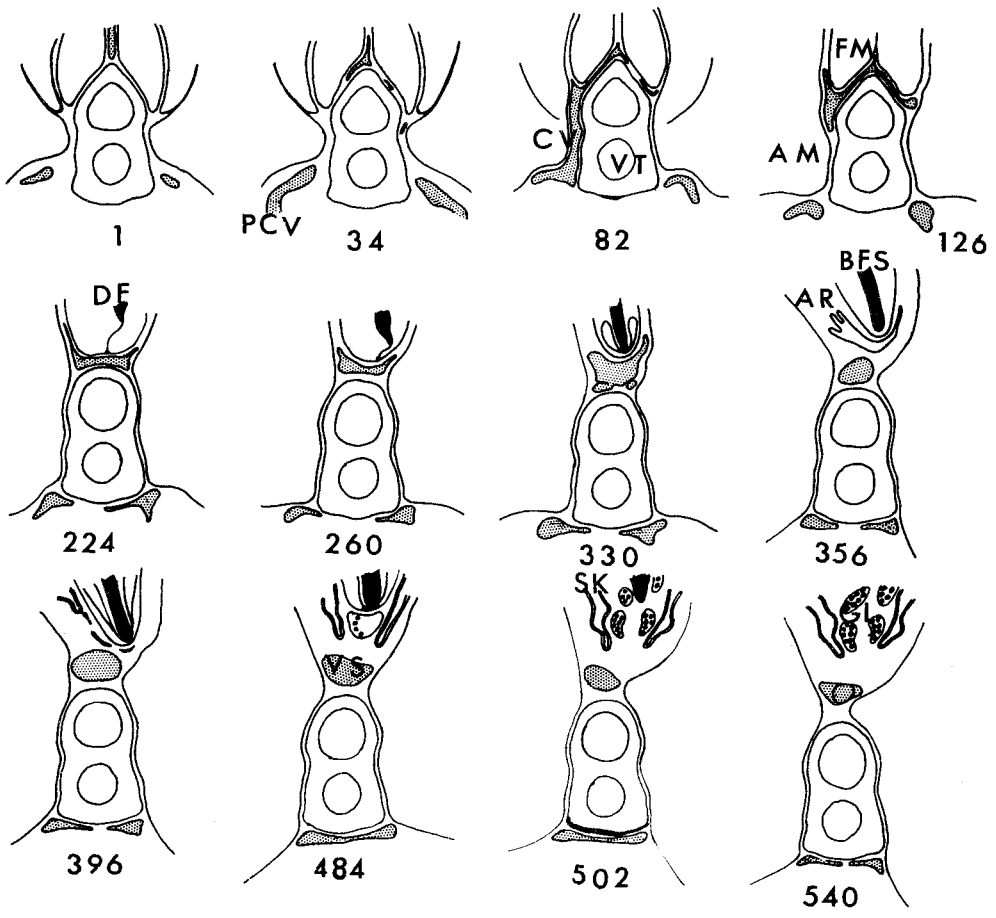

FIG. 2. - Outline sketches of the region of the vertebral column and the base of the anterior dorsal fin to show the relationships of the dorsal venous sinus to the fin, and the venous connection between the anterior end of the sinus and the left posterior cardinal vein, based upon serial sections of a specimen 27 cm long from tip of snout to end of tail.

The sketches carry numbers of the serial sections to which they correspond, the number "1" being given to the first section drawn.

Abbreviations -

AM axial musculature
AR areolar tissue separating dorsal fin from axial structure
BFS basal fin skeleton
CV communicating vein (profunda vein)
DF dorsal fin
FM anterior fin musculature
GL "glands" of origin of ceratotrichia
PCV posterior cardinal vein
SK skin
SL attachment of anterior fin muscles to basal fin skeleton
VS dorsal venous sinus
VT vertebral column

along a connecting vessel, and that the dorsal fin sinus was co-extensive with the attachment of the anterior dorsal fin to the trunk.

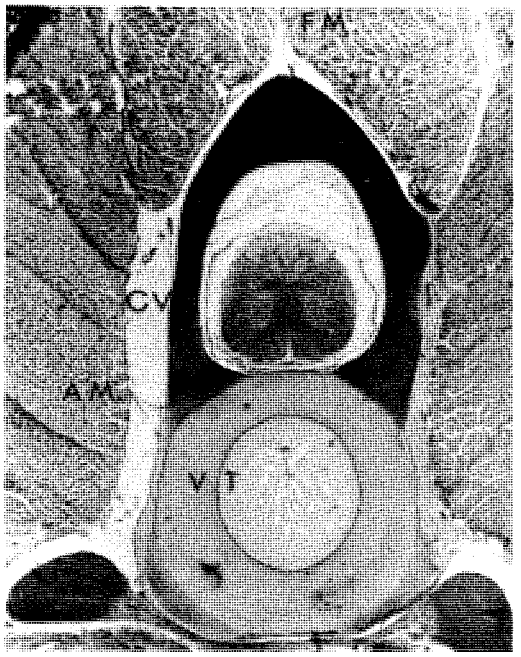

PLATE 1. - Section 92 of series of text-figure 2; shows communicating vein on left side of vertebral column joining dorsal longitudinal vein to posterior cardinal vein; abbreviations as for text-figure 2.

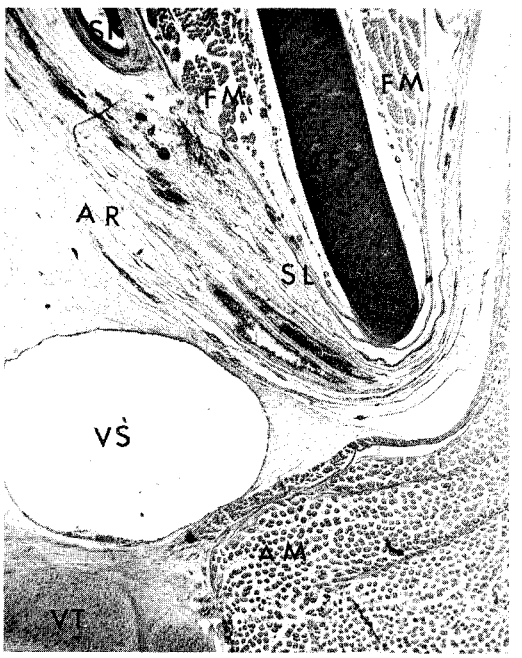

PLATE 2. - Section 396 of series of text-figure 2; shows relationships of dorsal venous sinus to vertebral column and to anterior dorsal fin in region of basal plate of fin skeleton; abbreviations as for text-figure 2.

The "dermal fin rays" of the anterior dorsal fin of *Callorhinchus* appear to take their origin in clusters of cells on each side of the basal plate. From these separate "glands" (plate 3) the ceratotrichia (Goodrich 1904) run upward, fanning out in the blade of the fin to form a closely set series of rays deep to the epidermis of each side.

Halstead and Bunker (1952) have found glandular tissue in the epidermis covering the anterior dorsal spine of the holocephalan *Hydrolagus colliei*, and they considered it to produce venom. Our *Callorhinchus* material was not sufficiently well preserved to make accurate observations on this point, but we have located a strip of vacuolated cells lying on each side of the origin of the thin double layer of epidermis connecting the dorsal spine to the blade of the fin, in the posterior interdentate region of the spine. The apices of these cells are directed to a shallow groove alongside the attachment of the double layer. These lines of epithelial cells seem to correspond in position and structure to those reported in *Chimaera* by Evans (1923). Whether the secretion of these cells contains venom or not requires further investigation; and the question must be asked, what is the biological function of such venom? There appear to be no records of any injuries having been received by man from *Callorhinchus* in Tasmania.

DISCUSSION

In both Selachii and Holocephali, cutaneous venous drainage takes place along

lateral cutaneous veins supplemented by dorsal and ventral cutaneous vessels. However, there is a structural difference between the two groups in regard to the dorsal cutaneous vein: in the Selachii this vein divides into venae circulares running on each side of the dorsal fin (Birch *et al.* 1969; Daniel 1934; Marples 1936; Mayer 1888; Parker 1886), while in the Holocephali there is a median dorsal fin sinus (Hanson, quoted by Satchell 1971; Stahl 1967). In both groups a vessel connects the dorsal cutaneous vein in the region of the anterior dorsal fin with deep vessels in the roof of the abdominal cavity. This profunda vein is given off from the dorsal cutaneous vein either just cranial to the dorsal fin sinus (Holocephali), or where the venae circulares join at the caudal end of the anterior dorsal fin to re-form the dorsal cutaneous vein (Selachii). The profunda vein usually passes to the left of the vertebral column, but in *Heterodontus* (Birch *et al.* 1969) it may pass on either side. The particular deep vein with which the profunda vein communicates depends upon the position of the anterior dorsal fin along the body, so that in *Squatina* (Marples 1936), where this fin lies far caudally, the profunda vein communicates with the caudal vein.

Edmund Charles Hobson was one of a small group of naturalists in Australia at a time when local interest in science was beginning to develop. The only local scientific journal in which such workers could publish their results was the *Tasmanian Journal of Natural Science* (Plomley 1969), and as well as his paper on *Callorhinchus* Hobson published in it some observations on the blood of the platypus and a number of notes on the geology and palaeontology of south-eastern Australia.

Hobson's finding in *Callorhinchus* "a vascular structure which I consider to be an accessory organ of respiration", and a supposed "communication with the gullet", are clearly wrong, though he was correct in seeing a significance in the movements of elevation and depression of the anterior dorsal fin. Evidently he was led into error by being able to press bubbles of air from the mass of spongy areolar tissue beneath the base of the fin. Air would readily be trapped in these tissues during dissection, and later could be pressed from them, as has been found in the present investigation. The functional significance of Hobson's observations is to be found in the structure of the venous system in elasmobranch fishes. In such fishes most of the veins are sinusoidal in form, and the blood in them is at very low pressure (Satchell 1971). Mechanisms are therefore needed to return blood to the heart, and these are essentially the pressures exerted on the vessels by somatic (c.f. Mayer 1888) and visceral movements, with direction of flow controlled by valves. In the Holocephali the flow of blood in the dorsal cutaneous vein is likely to be aided by movements of the anterior dorsal fin, and because the dorsal fin sinus is associated with a mass of areolar tissue, pressures developed at the base of the fin would be transmitted efficiently to the sinus.

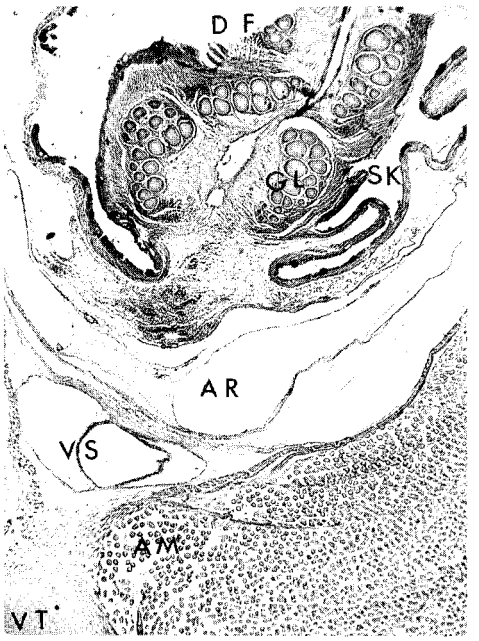

PLATE 3. - Section 536 of series of text-figure 2; shows relationships of dorsal venous sinus to vertebral column and to anterior dorsal fin in region behind basal plate of dorsal fin; abbreviations as for text-figure 2.

REFERENCES

Birch, N.P., Carre, C.G. and Satchell, G.H., 1969: Venous return in the trunk of the Port Jackson shark *Heterodontus portusjacksoni*. *J. Zool., Lond.*, 159, 31-49.

Daviel, J.F., 1934: THE ELASMOBRANCH FISHES. Berkeley.

Evans, H.M., 1923: The defensive spines of fishes, living and fossil, and the glandular structure in connection therewith, with observations on the nature of fish venom. *Phil. Trans. Roy. Soc. Lond.*, B 212, 1-33, pls. 1-3.

Goodrich, E.S., 1904: On the dermal fin-rays of fishes - living and extinct. *Quart. J. micr. Sci.*, 47, 465-522, pls. 35-41.

Halstead, B.W. and Bunker, N.C., 1952: The venom apparatus of the ratfish, *Hydrolagus colliei*. *Copeia* (for 1952), 128-138, 1 pl.

Hobson, E.C., 1841: On the *Callorhynchus Australis*. *Tas. J. nat. Sci.*, 1, 14-20, 2 pls.

Marples, B.J., 1936: The blood vascular system of the elasmobranch fish *Squatina squatina* (Linne). *Trans. roy. Soc. Edin.*, 58, 817-840.

Mayer, P., 1888: Ueber Eigenthumlichkeiten in den Kreislaufsorganen der Selachier. *Mitth. zool. Stat. Naepel*, 8, 307-373, pls. 16-18.

Parker, T.J., 1886: On the blood-vessels of *Mustelus antarcticus:* a contribution to the morphology of the vascular system in the Vertebrata. *Phil. Trans. Roy. Soc. Lond.*, 177, 685-732, pls. 34-37.

Plomley, N.J.B., 1969: The Tasmanian Journal of Natural Science. *Pap. Proc. roy. Soc. Tasm.*, 103, 13-15.

Satchell, G.H., 1971: CIRCULATION IN FISHES. Cambridge.

Stahl, B.J., 1967: Morphology and relationships of the Holocephali with special reference to the venous system. *Bull. Mus. comp. Zool.*, 135, 141-213, (pls. 1-10).