

INTERNAL ANATOMY OF SELACHII  
FROM THE NORTH-WESTERN RED SEA

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## I.—INTRODUCTION

It is well known that the elasmobranchs represent an important group of fishes, as they are among the earliest representatives of the class and have succeeded in retaining many primitive characters, which they inherited from remote ancestors. Such characters, retained for so long, must be particularly adapted for their marine life. While some elasmobranchs have systems so generalized as to represent a general plan on which vertebrate life is built, others—though simple in some systems—are characterized by great specialization in some respects. Some elasmobranchs are small, others attain large sizes, and in fact the largest fish known are among the elasmobranchs. Some are oviparous, others are ovi-viparous and others still are viviparous, but in all cases the eggs are large and fully charged with yolk, and the young hatch from their eggs fully equipped to earn their living and find for themselves. Some are active swimmers, have predaceous habit and graceful form, others are ungainly, clumsy and slow in motion.

For these reasons, this group attracted the attention of a great many authors from early times, and numerous works, dealing with representatives of this group in different parts of the world, have been published. Among these, mention may be made of Owen (1866), Balfour (1876-78), Parker (1879), Haswell (1884), Goodrich (1909), Allis (1914 and 1923), Daniel (1915-34), Boulenger (1923), De Beer (1926-37), and others.

The elasmobranchs of the Red Sea, however, have not received any attention from the points of view of their anatomy, ecology or physiology. We, therefore, give here an account of the anatomy of some representative members of our area. Such an account may serve as a useful basis for further work and has already proved of value in solving some of the points of confusion in the taxonomy of the group, dealt with in our previous paper.

Special attention has been given to a comparison of the different systems in the selachoids and batoids as well as the transitional forms, and the place these occupy between the two groups.

## II.—MATERIAL AND METHODS

The Oceanographic Institute, with its laboratories at Al-Ghardaqa and 'Ataqa (Suez), was the main centre of collection.

Eight main species, belonging to the two orders Selachii and Batoidei have been selected for this comparative anatomical study, and representing six families having different habits and habitats. Four species belong to the Selachii, namely *Galeocerdo cuvier* (Peron and Lesueur), *Aprionodon brevipinna* (Müller and Henle), *Carcharhinus melanopterus* (Quoy and Gaimard), family Carcharhinidae; and *Nebrius concolor* Rüppell, family Orectolobidae.

The Batoidei are represented by two species viz :

*Teniura lymma* (Forskål), family Dasyatidae; and *Aëtobatus narinari* (Euphrasen), family Aëtobatidae.

*Rhinobatos halavi* (Forskål), family Rhinobatidae and *Rhynchobatus djiddensis* (Forskål) Family Rhynchobatidae are two intermediate forms.

The arrangement of the internal viscera *in situ*, sex, condition of maturity of the gonads and the number and size of embryos, when present, etc. were noted.

In all specimens obtained, the stomachic and intestinal contents were collected for the investigation of the nature of the food, the stomachs and intestines were cut open and the valvular intestine examined.

The viscera were injected with 10% formaline, and then preserved in a 5% formaline solution for further study. In fresh specimens, the ventral aorta was injected with warm coloured gelatin mass for the study of the heart with its vessels while *in situ*, and the whole was preserved, for the study of the valves and the coronary vessels.

The skull was injected with 40 % formaldehyde solution, the brain was studied *in situ* before being taken out of the chondrocranium for detailed investigation. The head skeleton of several adult specimens was prepared.

Some advanced foeti, in which the skeletal parts were completely developed were stained with methylene blue according to van Wijhe's method (1902) for studying the head skeleton. They were left for about a week in methylene blue, then differentiated in several changes of acid-alcohol. Stained specimens, dissected under the binocular microscope, as well as hand-sectioned in different directions were of great value in showing details not clear in skulls of adult specimens.



### III.—INTERNAL ANATOMY OF REPRESENTATIVE SPECIES

#### 1. Digestive System

Elasmobranchs, as far as we know, are completely carnivorous, even the few genera such as *Manta* and *Cetorhinus* which are plankton feeders subsist on animal plankton; and we do not know so far of any herbivorous elasmobranch. The type of food is reflected on the structure and extent of development of the teeth, thus the molar type of teeth, present in bony fishes, is not represented in elasmobranchs.

In the free swimming sharks the teeth are prehensile, provided with one or more cusps to grasp the food. Rays, in contrast to sharks, are mainly slow movers and can only get hold of either sedentary or slow moving animals, thus they feed mostly on molluscs, crustaceans etc. For this reason the teeth are of the pavement type throughout, serving for crushing. Rays, such as *Taniura lymma*, feeding on slippery animals like annelids, dead or slow moving bottom fish, may have pavement teeth provided with sharp points or cusps.

In contradistinction with teleosts, in which the general form of the alimentary tract in relation to nutrition has often been considered to indicate a taxonomic integrity (Hubbs and Turner, 1939), the elasmobranchs are characterized by a fair degree of uniformity in the structure of the alimentary tract. Thus, in all of them, it is generally short in comparison with the body length, and there is always a well developed stomach and no stomachless elasmobranch has, as far as we know, been recorded. They also all possess a valvular intestine though the type of the valve may differ. The spiral valve is a special adaptational contrivance for increasing the absorptive surface of the intestine, not met with in other categories of fish.

#### *Mouth and Bucco-pharyngeal Cavity.*

In *Galeocerdo cuvier*, the large crescent-shaped ventral mouth (Pl. I, Fig. 1) leads into a spacious buccal cavity, the floor of which is raised up to form the so-called tongue. The mucous lining is thrown anteriorly into thick folds which cover the non-functional overlapping teeth. The buccal cavity continues insensibly into the pharynx which is characterized by a small spiracular pouch, followed by five branchial pouches, extending from the pharyngeal walls on either side. The bucco-pharyngeal cavity is lined by a mucous membrane perforated by the stomodaeal denticles (described before, Gohar and Mazhar, 1964) which correspond to the large real teeth, with siezing sharp-pointed tips and cutting edges, in the region of the jaws.

In *Nebrius concolor*, the mouth is much smaller than that of *Galeocerdo cuvier* and leads directly to the bucco-pharyngeal cavity, being in turn smaller and more dorsoventrally depressed. The teeth are small and adapted for snapping the corals and small sand-living invertebrates.

*Taniura lymma*, which is a bottom living ray, still possesses a markedly smaller mouth than the two described sharks. The very small teeth (Pl. II, Figs. 2 and 3) with cusps pointing posteriorly are suitable for securing the slippery bottom worms, mainly polychaetes, which proved to form most of their diet. The mouth leads into a dorsoventrally depressed buccopharyngeal cavity, which is markedly lower than in sharks. The mucous lining of the roof is thrown anteriorly into a thick fold, covering the non-functional posterior teeth which occupy the hind third of the tooth-plate. From the inner margin of the fold, a valve hangs down in the buccal cavity. Its free posterior margin is incurved and fringed as is the case in most rays (Owen, 1866). This valve is homologous to the maxillary breathing valve described in teleosts and some elasmobranchs by Gudger (1936 & 1946). Posterior to the upper valve, the lining of the buccal cavity is thrown into three elevated ridges, one median and two lateral. The median ridge is higher and straight, while the laterals are antero-posteriorly and outwardly oblique. All the three ridges end posteriorly at the beginning of the pharyngeal cavity. Inward to each internal spiracular opening, the pharyngeal lining is thrown into an oblique ridge which begins at the base of the buccal median ridge and becomes oblique outwards towards the internal spiracular opening. Another ridge extends in the middle of the pharyngeal roof from between the second pair of internal branchial openings rearwards to the end of the pharynx.

The lining of the floor of the buccal cavity extends anteriorly forming the lower valve «mandibular valve» which is smaller than the upper, has a smooth anterior margin and is directed upwards. At the middle part of this valve, arise two fleshy oral papillae directed dorso-posteriorly. In between these, and in a somewhat anterior level to them is a minute third papilla. Three elevated ridges extend in the floor from a distance somewhat posterior to the oral papillae backwards till the level of the third internal branchial opening. Following these are another two oblique folds on each side of the posteriormost part of the pharynx. On the margins of the branchial arches are 10-12 small knobule-like projections which resemble incipient gill-rakers.

In *Aetobatus narinari*, both of the upper and lower valves are well developed. The upper valve (Gohar and Mazhar, 1964, pl. XV, Fig. 5) is nearly rectangular and its free margin is coarsely fringed, but the anterior portion covering the posterior part of the tooth-band has two transverse rows of mamillae, the upper



with seven mamillae and the posterior row with only four. The lower valve (Gohar and Mazhar, 1964 pl.XV, Fig. 4) has some mamillae, ranging from 6 to 8, beside these are 6-7 knobules of different size and other fringed extensions, all surrounding the valve on its posterior attached surfaces without order. The roof and floor of the bucco-pharyngeal cavity are fleshy, smooth and devoid of any denticle. As in *T. lymma*, small knobule-like projections ranging from 12 to 15 are found on the margins of the branchial arches.

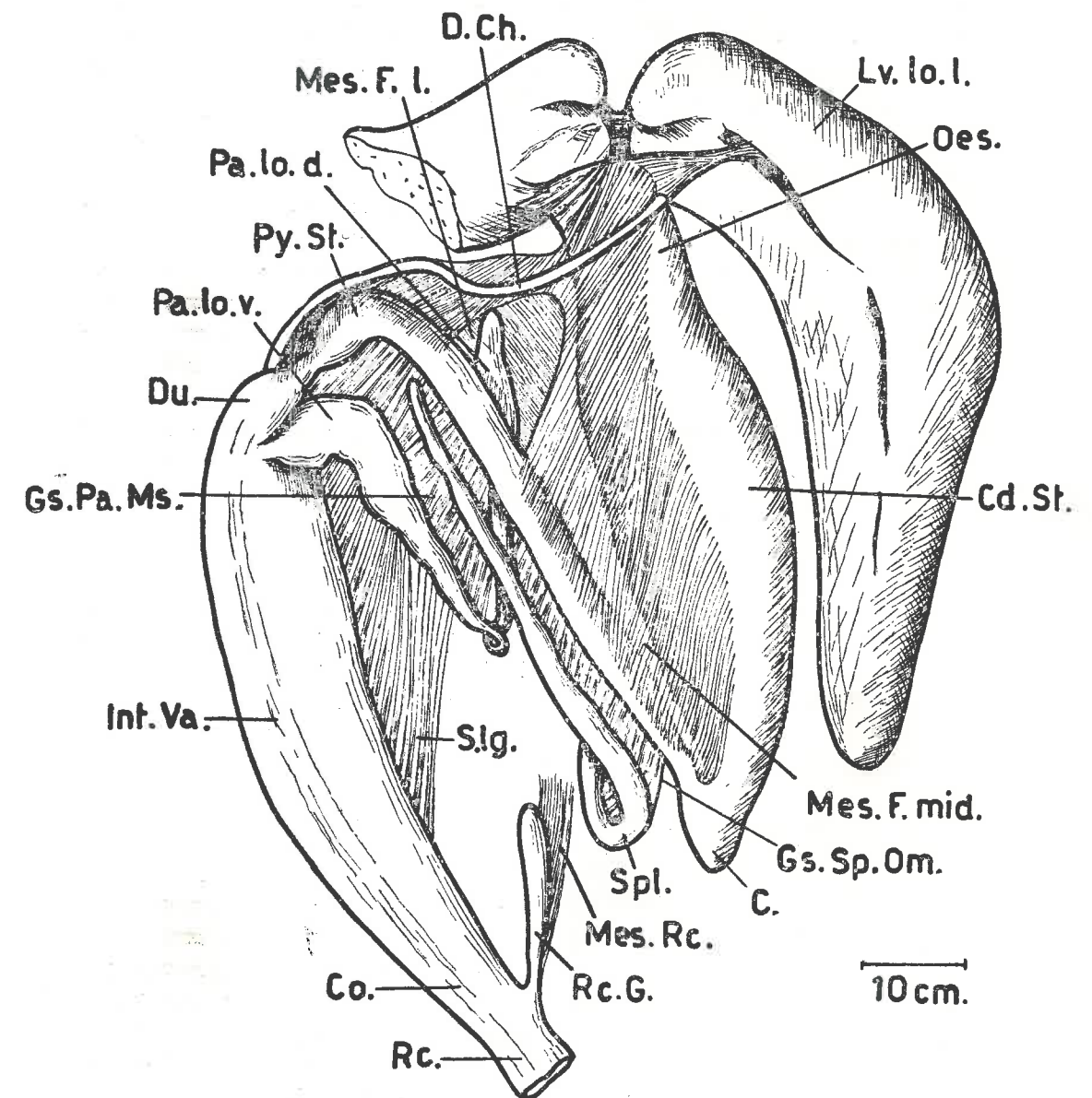
In the transitional forms *Rhynchobatus djiddensis* and *Rhinobatos halavi*, the relatively small mouth, carries small numerous teeth which form a mosaic-like pavement, and are adapted for bottom food, mostly of crustaceans. The mouth is followed—as is the usual case in rays—as by the depressed bucco-pharyngeal cavity, which is much lower than that of sharks. Still, the upper and lower valves are well developed. The upper valve has its free posterior margin straight near the corners of the mouth then it is provided with two convex protrusions one on either side, and the middle-part, in between these, is concave. The upper edge of the lower valve is emarginate, with the middle fourth nearly straight and the sides concave. As in *Taeniura lymma* and *Aetobatus narinari*, the branchial arches have about 14 small projecting knobules.

In the batoids described above, where the «mandibular» and «maxillary» valves are well-developed, the water current for respiration enters through the large spiracles into the buccal cavity, the spiracles, then, close while the mouth remains partly open, but the well-developed buccal valves prevent—except a little—the water current from going out through the mouth, the water being forced to pass over the gills on its way outwards through the gill-slits which lie on the ventral side of the head.

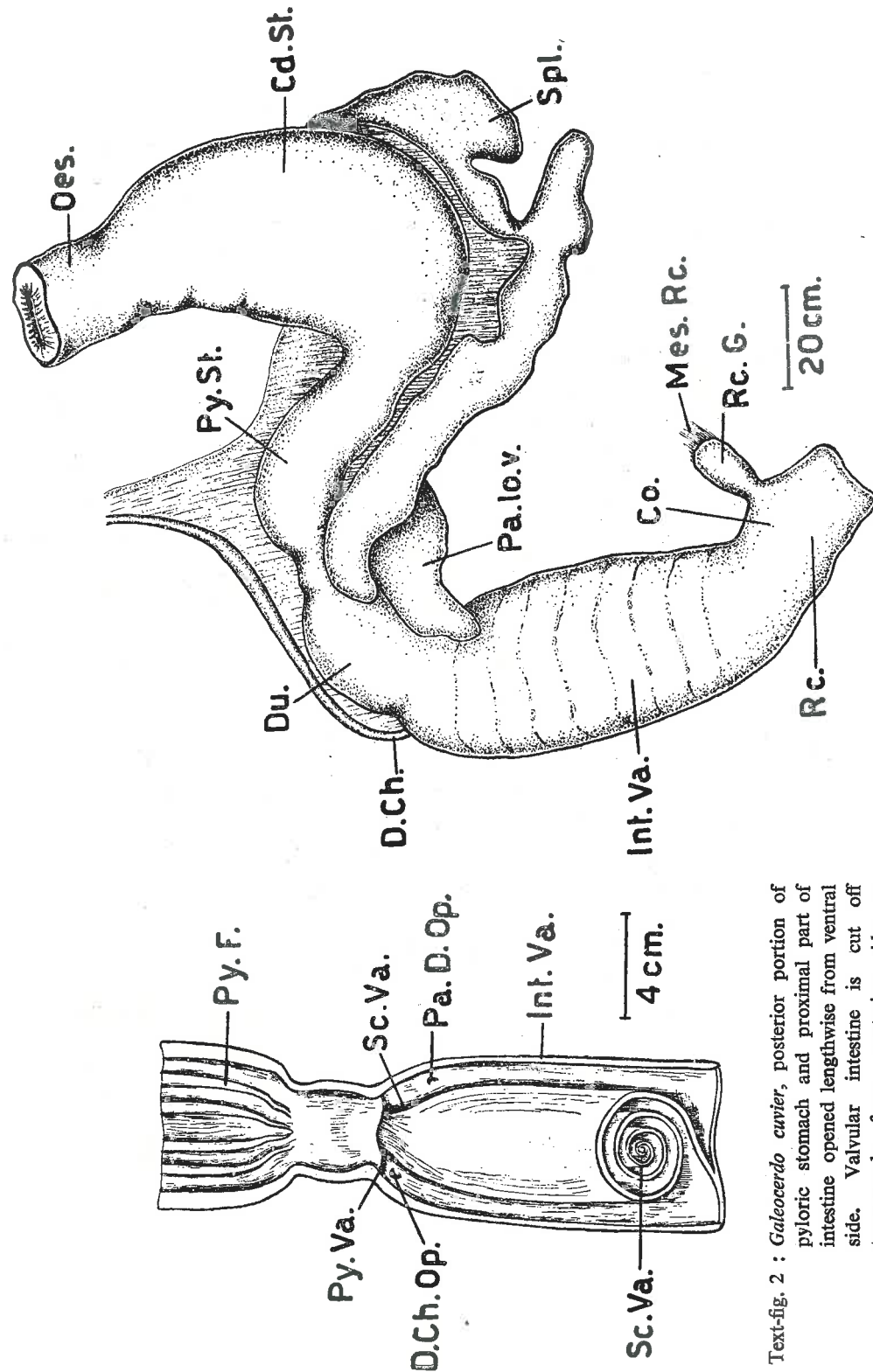
#### Oesophagus :

Posteriorly, the pharynx narrows into a short thick-walled tube, the oesophagus, which lies dorsal to the liver and curves towards the left side leading into the wide stomach (Text-figs. 1, 3 & 4 and Pl. II, Fig. 4). Externally, the oesophagus can be demarcated posteriorly from the stomach by a slight constriction between the two regions. As usual in fishes, the muscular coat of the oesophagus is formed of striated muscles, an outer longitudinal layer and an inner circular one. This coat reaches its maximum thickness in *Nebrius concolor* (Pl. I, Fig. 4).

Internally, the oesophageal lining is thrown into a wrinkled surface in *Galeocerdo cuvier* (Pl. I, Fig. 2), but in *N. concolor* it is thrown into thick high parallel longitudinal folds ranging from 10 to 14 in number. These are slightly wavy with smooth surfaces but tend to be papillated only at their posterior-most portions. The lining forms a wrinkled belt at the junction between the oesophagus and the stomach.



Text-fig. 1 : *Galeocerdo cuvier*, ventral view of alimentary tract of an adult specimen, a portion of the mesentery removed to show the underlying organs.

Text-fig. 3 : *Nebrius concolor*, ventral view of alimentary tract of adult.Text-fig. 2 : *Galeocerdo cuvier*, posterior portion of pyloric stomach and proximal part of intestine opened lengthwise from ventral side. Valvular intestine is cut off transversely from posterior side to show nature of valve.

In *Tæniura lymma*, the lining is thrown into small papillae (Text-fig. 6) arranged in about 16 transverse bands. These are in turn, arranged successively in two longitudinal rows. The anterior transverse bands are larger, decreasing in breadth towards the stomach and disappearing at the junction with the stomach, where they are replaced by a slightly folded area.

*Mobula kühlîi* has the oesophageal lining thrown into small papillae (Pl. III, Fig. 3) arranged in numerous transverse parallel rows (about 160), which are in turn, arranged in four longitudinal parallel series. The anteriormost papillae are larger than the posterior ones. Rearwards, towards the stomach, the lining forms a transverse band of short, thick, longitudinal parallel folds.

About 10 longitudinal folds, of irregular thickness and with the upper surfaces irregularly divided into finger-like papillae, extend along the oesophagus in *Aëtobatus narinari*.

In *Rhynchobatus djiddensis* (Pl. IV, Fig. 2) the anterior third of the oesophagus is lined by frilled villi, and about 11 longitudinal irregular thick folds, with small frilled villi in between, extend posteriorly to the rear end.

In *Rhinobatos halavi* (Pl. IV, Fig. 4), the whole length of the oesophagus is lined with longitudinal folds (about 12), between which the spaces are occupied with frilled villi.

#### Stomach :

As is the case in most sharks, the stomach in *Galeocerdo cuvier* (Text-fig. 1) is a more or less U-shaped tube, of which the right limb, the cardiac region, is wide and ends posteriorly in a small caecum. The pyloric region is narrow, thick-walled and ends posteriorly in a small bulb. The mucous lining of the stomach is a continuation of that of the oesophagus and is thrown into irregularly corrugated walls.

The cardiac stomach is capable of distension according to the quantity of food. Half a human partly digested body was found in the stomach of one of these sharks, and the anterior half of a large ray was found in another. Longitudinal thin folds line the caecal part. Thicker folds extend along the whole length of the pyloric wall and so the lumen becomes very narrow. The lining becomes more or less smooth in the posterior bulge which ends by the pyloric valve leading to the intestine.

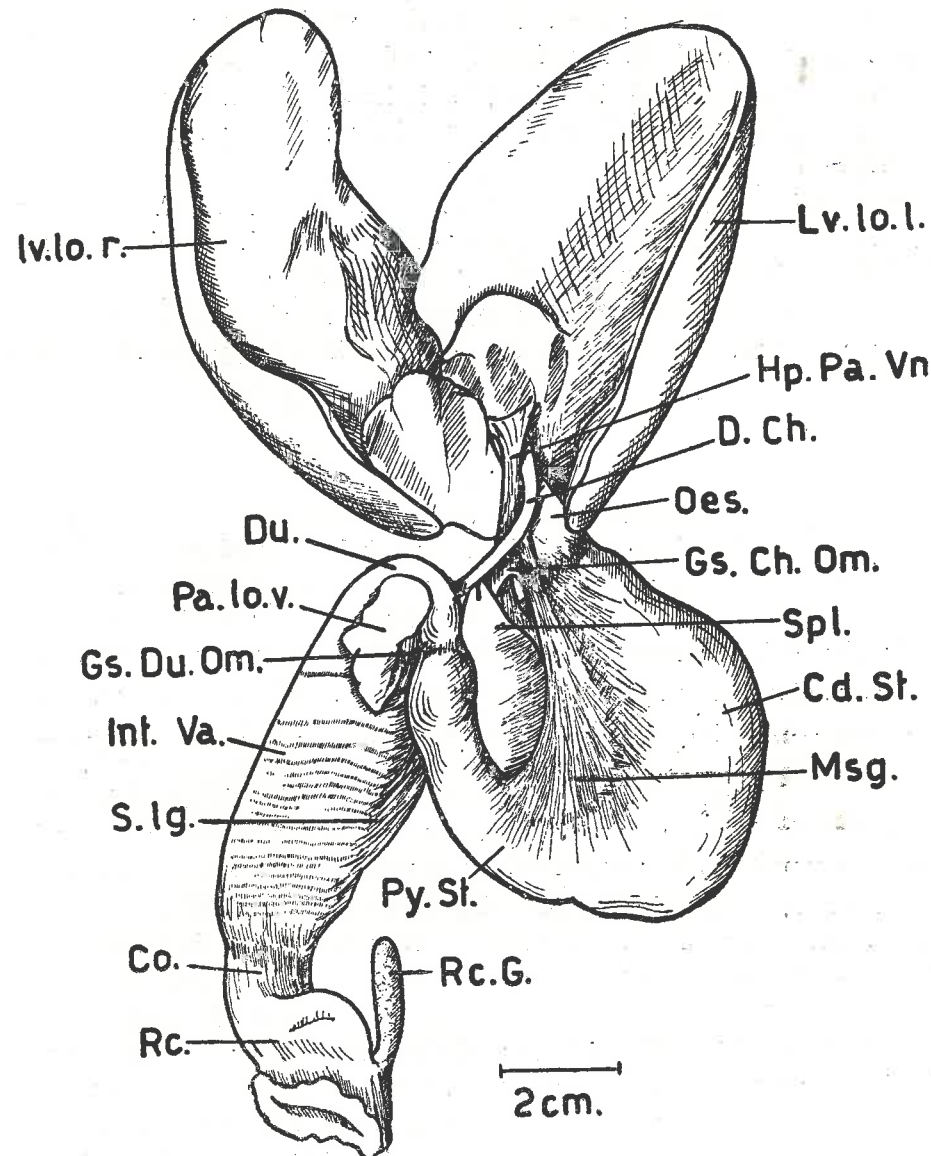
The passage of large pieces of partly digested food into the intestine is efficiently guarded against by the narrow lumen of the pyloric limb, the thickness and indensibility of its wall as well as by the action of the pyloric sphincter.

The stomach of *Nebrius concolor* (Text-fig. 3) is J-shaped, the cardiac portion forms the longer right limb and is about double the pyloric limb. The former is dilated and slopes into the latter which is much narrower, but no caecum exists at the end of the cardiac portion. The walls are more highly muscular than those of *G. cuvier*. The internal mucous lining is thrown into many longitudinal parallel

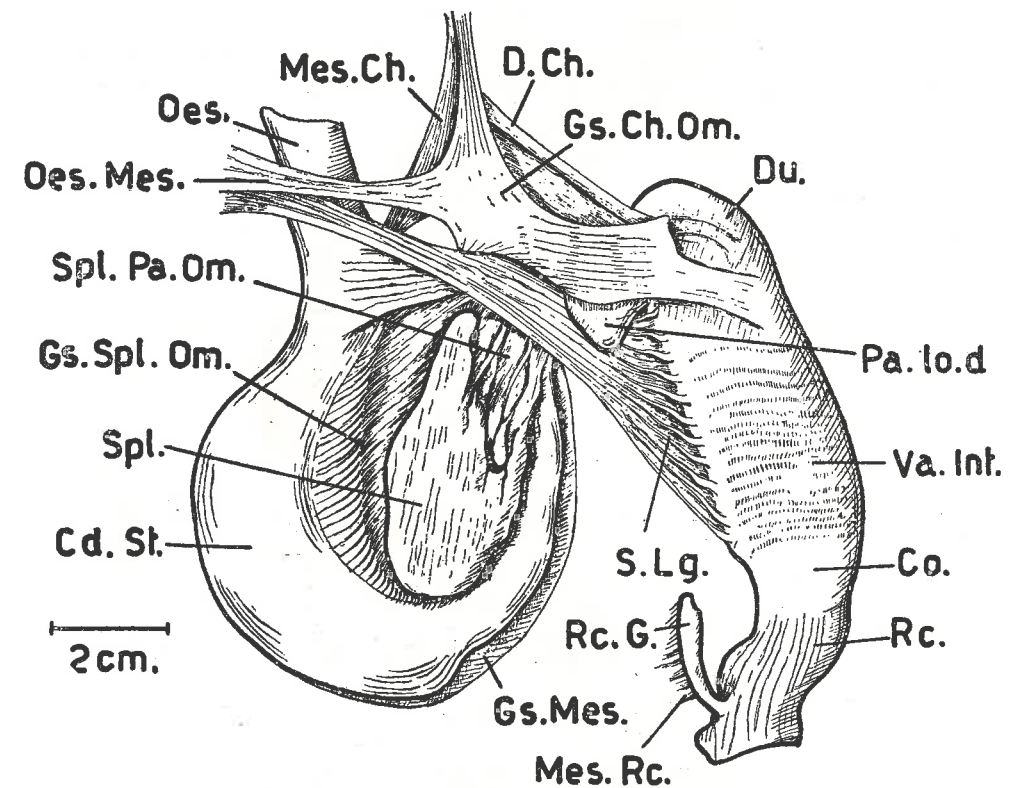


folds (about 40) which pass along the cardiac stomach (Pl. I, Fig. 4) and decrease greatly in number in the pyloric portion (Pl. II, Fig. 1) until a middle clear high ridge is left which passes posteriorly along the constricted bulb and ends finally in the pyloric valve. The latter projects as a well-defined circular band into the anterior part of the duodenum.

In the ray, *Taeniura lymma*, the cardiac stomach is somewhat longer than the pyloric division, (Text-fig. 4) and extends as a distended bag ending with a slightly protruded left part, marking the place of the blind sac in sharks. The thick-walled



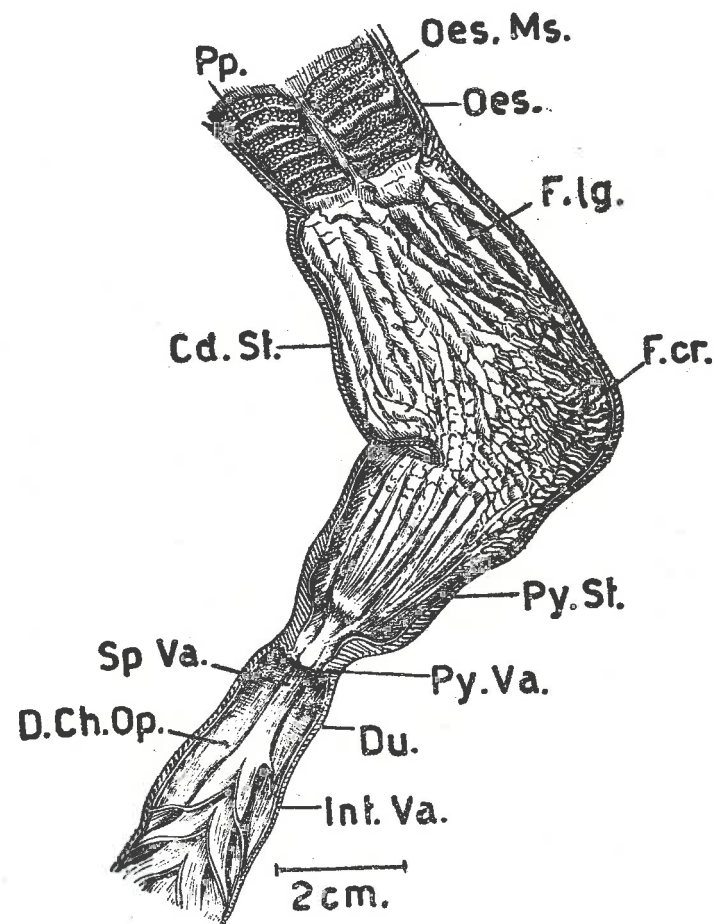
Text-fig. 4 : *Taeniura lymma*, ventral view of alimentary tract of adult.



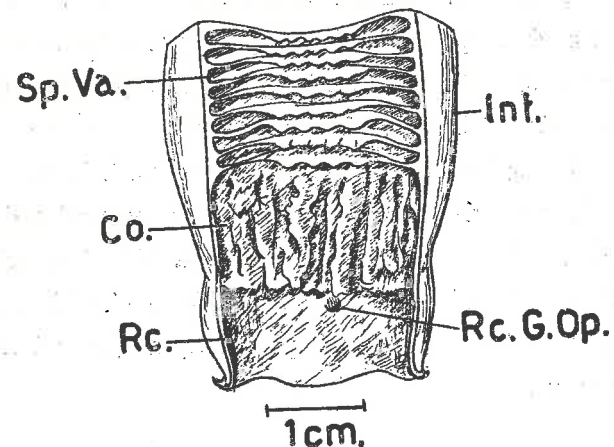
Text-fig. 5 : *Taeniura lymma*, Dorsal view of alimentary tract of adult.

slender pyloric limb has a highly muscular hind bulb leading at the end to a smaller one. Internally (Text-fig. 6), the stomach-wall is less muscular than the oesophageal wall but it thickens gradually posteriorly in the pyloric stomach towards the posterior two bulges. The lining of the stomach is thrown into pronounced longitudinal highly convoluted folds. These pass backward giving rise to numerous irregular smaller ones which abut against the bulging wall representing the blind sac. Towards the pyloric stomach, the folds gradually become less convoluted and then straight passing towards the middle where they unite forming a thick elevated knob forming the first bulb. As a continuation to this knob, a middle high fold extends along the dorsal wall of the second bulge, and ends posteriorly at the end of the circular pyloric sphincter valve.





Text-fig. 6 : *Taeniura lymma*, hind part of oesophagus, stomach and proximal portion of spiral intestine opened lengthwise ventrally to show internal lining.



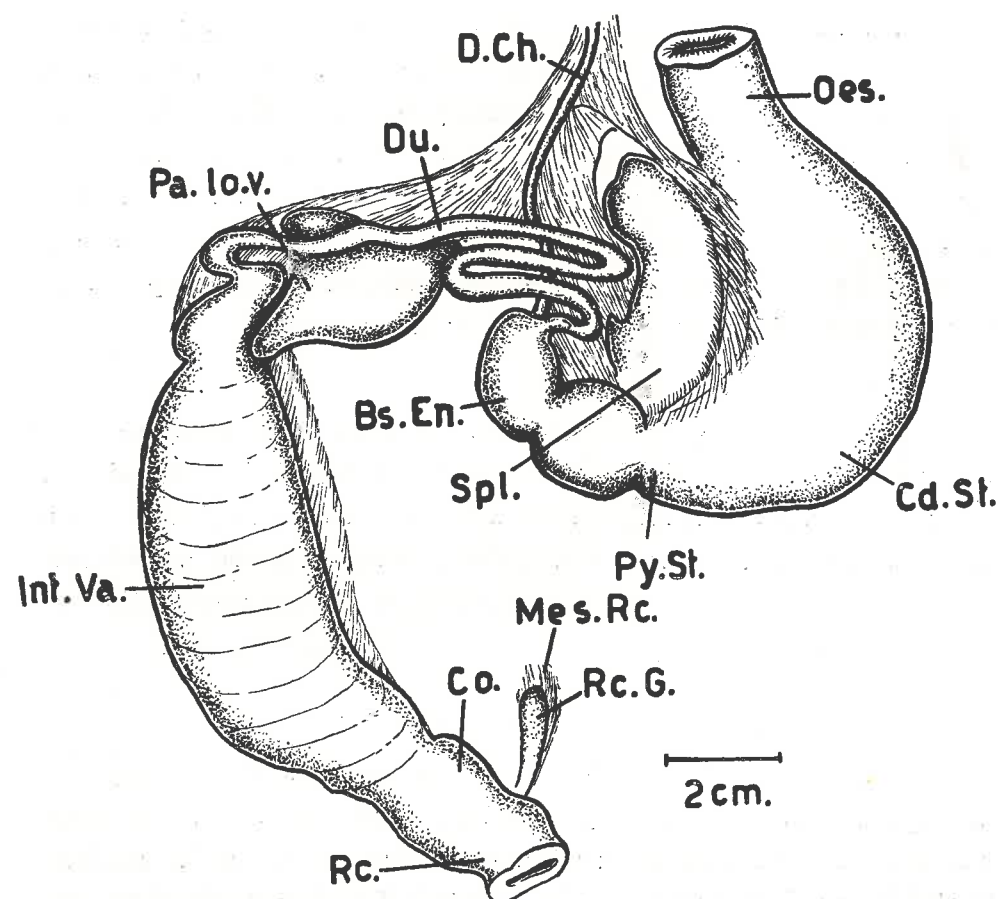
Text-fig. 7 : *Taeniura lymma*, posterior part of spiral intestine together with colon and rectum opened lengthwise from ventral side to show internal structure.

The stomach of *Aëtobatus narinari* resembles morphologically that of *Taeniura lymma* and differs only in having a single posterior bulb. Internally the mucous lining is thrown into papillae (Pl. III, Fig. 1), which are thin, broad and high at the anterior half of the cardiac stomach, gradually becoming thicker, shorter and finger-like rearwards along the rest of the cardiac surface and extending on the pyloric surface to a relatively small distance before the end is reached. The lining is then thrown into thick folds (Pl. III, Fig. 2) occupying the region of the bulb, obliquely extending from the sides towards the middle, where they are replaced by a very thick v-shaped high pyloric fold ending by the pyloric valve.

*Mobula Kühlii* has also a J-shaped stomach (Text-fig. 8) which ends posteriorly by a marked bulge, constricted anteriorly as well as posteriorly. Internally, the lining of the cardiac stomach is thrown into many oblique, wavy ridges (about 15-19) passing with the curvature of the stomach towards the middle, and becoming narrower backwards and extend as V-shaped to the anterior pyloric region (Pl. III, figs. 3 and 4).

In the following region extending to the beginning of the bulb, the ridges lose their arrangement. Here, the lining is raised to an egg-like bulge on the inner middle portion of the dorsal wall. Longitudinal wavy ridges extend from the apex backwards covering the surface of this bulge. On both dorso-lateral sides of the latter, the lining is thrown into an oblique band, striped by a row of parallel short wavy ridges beginning just close to the middle of the bulge and passing outwards. The pyloric limb ends then in the constricted pyloric valve, leading to the proximal part of the intestine.

The transitional species, *Rhynchobatus djiddensis*, has a highly muscular stomach (Pl. IV, Fig. 2), in which the cardiac and pyloric limbs are equal. Internally, the mucous lining is thrown into about 40 high flattened parallel longitudinal ridges each of which is transversely divided, and thus, the upper edges are coarsely fringed. In the pyloric region, the ridges are much lowered into irregular, zigzagged striated folds. These end at the pyloric valve.



Text-fig. 8 : *Mobula kühlii*, ventral view of alimentary tract of an adult.

The stomach of *Rhinobatos halavi* resembles morphologically that of *R. djiddensis*. Internally, 18-20 longitudinal parallel high ridges, as continuations to those lining the oesophagus, pass rearwards lining the cardiac stomach. At the posterior part leading to the pyloric stomach, the ridges are reduced in number and each is divided into small pads by means of transverse, or by transverse as well as longitudinal, constrictions. There are about eight ridges along the pyloric limb, which are much narrower and higher than those of the cardiac portion. They are straight and extend posteriorly to the pyloric valve, which is well-developed and projects rearwards into the duodenum.

# Intestine :

## A.—Duodenum :

The stomach leads into the intestine by means of the pyloric valve. The anteriormost portion of the intestine which receives the bile and pancreatic ducts is the duodenum or middle intestine.

Daniel (1934) stated that «the duodenum is variable in different elasmobranchs. In a type like *Spinax niger*, the valve-free portion is long. This segment is present in *Rhinobatis*, but of all the rays, it is best developed in *Trygon*. In the great majority of types, however, the valve has so encroached upon the pylorus that no free portion exists e. g. *Galeus*, *Carcharias*, Lamnidae, Notidanidae, Scyllidae, Rhinidae, and some of the Rajidae».

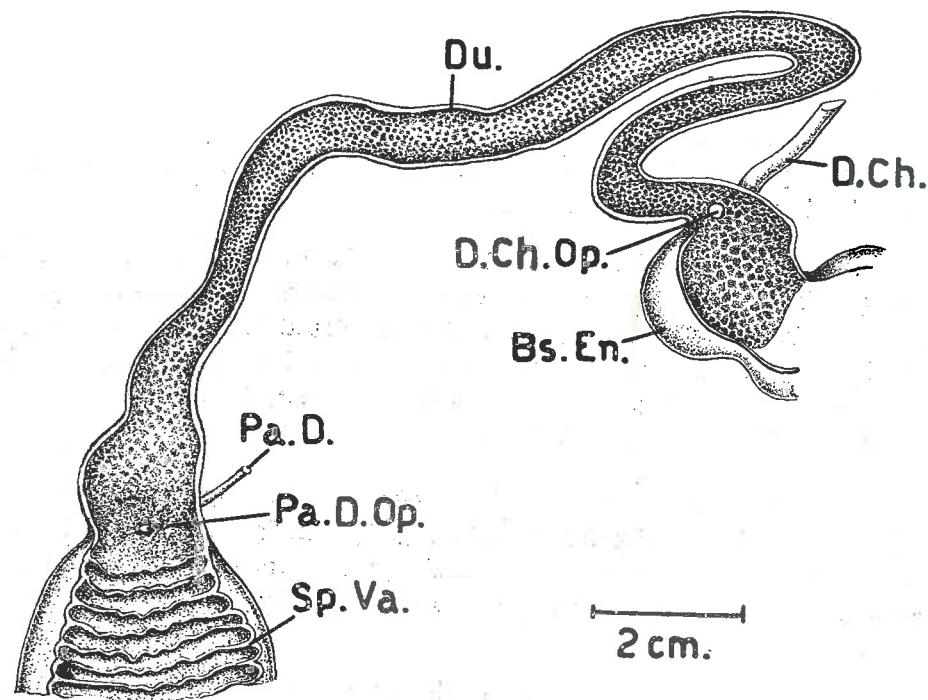
*Galeocerdo cuvier*, *Nebrius concolor*, *Teniura lymma*, *Rhynchobatus djiddensis* and *Rhinobatos halavi* (Text-fig. 2, Pl. II, Fig. 1, Text-fig. 6, Pl. IV, Fig. 3 and Pl. IV, Fig. 5 respectively), resemble the majority of elasmobranchs in having the intestinal valve touching the pyloric valve and accordingly no valvular-free portion is left.

*Aëtobatus narinari* differs from the above-mentioned species in possessing a valve-free duodenum (Pl. III, Fig. 2) which is rounded, and highly muscular. Internally, its mucous lining is thrown into very low papillae covering the corrugated internal surface. At the anteriormost portion of the duodenum, and just posterior to the pyloric valve, the lining is thrown into a small papillated oblique ridge, protruding from the right dorsal wall and perforated by the bile duct. A little distance posterior to this protruding ridge, arises a larger one extending from the right side to the left and covered by small papillae. This ridge protrudes into the cavity of the duodenum forming a narrow lumen in between it and the pyloric end. This duodenal part leads posteriorly to the valvular portion of the intestine.

In *Mobula kühlii* (Text-figs. 8 and 9) the duodenum is preceded by a rounded bulge, the bursa entiana. This occurs just posterior to the constriction of the pyloric valve, and leads posteriorly (at its left dorso-lateral wall) to the duodenum.

Redeke (1900) described the bursa entiana in *Eugaleus galeus*, and mentioned that the true bursa entiana is a separate chamber of the gut on the proximal side of the pylorus, and is thus a specialized part of the pyloric limb of the stomach. Matthews and Parker (1950) referred to the bursa entiana in *Cetorhinus*, as follows : «*Cetorhinus* like *Eugaleus* possesses a very distinct bursa entiana but unlike that species it also possesses a distinct duodenum which forms a well-marked chamber proximal to the beginning of the spiral valve, though it is not constricted off from it as a separate region visible externally».





Text-fig. 9 : *Mobula kuhlii*, part of alimentary canal from behind stomach to anterior portion of valvular intestine cut lengthwise along ventral side.

In *Mobula*, the bursa entiana shows, internally, the same structure as the duodenum (Text-fig. 7). Both are thin-walled and have the mucous lining thrown into very thin anastomosing folds, forming a net-like internal wall. Accordingly, the bursa entiana is considered as a part of the intestine and not of the pyloric stomach as considered by Redeke (1900). It is clear here that the thin-walled bursa entiana functions as a receptacle for the food emptied by the pylorus, before it is allowed to pass gradually into the duodenum.

*Mobula* is probably the sole genus of the elasmobranchs which has an excessively long duodenum, formed of a narrow convoluted tube, longer than both the stomach and the spiral intestine together. Posteriorly, the duodenum ends in a bulge, wider than the rest of the tube and constricted at its rear end leading to the spiral intestine.

This portion of the intestine was given different names by different authors. Thus Mazza (1891) referred to it in *Cephaloptera giornae* as the «primary portion of the mid-intestine», while Whitley (1936) described it as «the narrow post-pyloric portion (median intestine)». Gohar and Bayoumi (1959) used the term duodenum in their description to this part being rather long in *Manta ehrenbergi*.

All the above described species — except *Mobula kuhlii* agree with the general rule in elasmobranchs where the bile duct as well as the pancreatic duct opens not far from one another, into the dorsal side of the anterior portion of the duodenum. *Mobula diabolus*, on the other hand, shows a different state of affairs (Text-fig. 9), as the bile duct opens on the dorsal surface at the end of the bursa entiana leading to the first portion of the duodenum, while the pancreatic duct opens on the dorsal wall at the end of the long convoluted duodenum just before the valvular intestine.

#### B.—Valvular intestine.

This is the portion that follows the duodenum and leads posteriorly to the colon and forms the largest part of the intestine. Within the lumen of the valvular intestine lies a fold or valve which is characteristic to the elasmobranchs, and grows from the lining of the intestine.

A number of valuable contributions have been made by several authors regarding the valvular intestine in elasmobranchs. Of these may be mentioned Parker (1879), Garman (1913), White (1936) and Ishiyama (1958). White (1936) classified the valves of elasmobranchs into three types according to their form. These are : the scroll, the spiral and the ring types. To these types we add a fourth, the spiro-annular type.

In members of the Carcharhinidae as exemplified by *Galeocerdo cuvier* the valve is a single fold, rolled up into a scroll (Text-fig. 2). One side of the fold is attached dorsally to the internal wall along the entire length, and the free edge of the fold is rolled up longitudinally on its axis and parallel to the axis of the intestine (dextrally), forming four turns. The internal surface of the valve is thrown into multitudinous tiny villi.

In *Nebrius concolor*, *Teniura lymma*, and *Rhinobatos halavi* (Pl. II, Fig 1, Text-fig. 6 and Pl. IV, Fig. 5, respectively) the valvular fold originates as a thick column at the beginning of the duodenum, extending along its whole length attached to the dorsal side, and passing posteriorly along the valvular intestine. The column winds spirally around a central axis free from the intestinal wall, forming successive valves, the outer edges of which are attached to the walls of the intestine and each valve is continuous with the adjacent one and with the axis.

The number of turns is fixed for any one species but varies from one to another. Thus, in *N. concolor* the number of valvular turns is 24, of which the anterior three are widely spaced. So that they appear as concentric cones pointing anteriorly, the succeeding 12 turns are very close together and appear as rings, and the last turns appear as backwardly directed cones. The whole surface of the valve is covered by small papillae.



*Teniura lymma* has only 19 turns of the valve, the anterior 10 are cone-like and point forwards, the rest (Text-fig. 7) are disc-like succeeding one another so closely that the central axis is not clear and can only be seen by careful examination. The free central edge of the valve is thrown into high processes, which vary in number. The surface of the valve appears smooth but, when examined with a magnifying lens, multitudes of tiny villi are seen covering the whole surface.

The number of turns of the valve is greatly reduced in *Rhinobatos halavi*, where there are only 10, and thus the conical shape of the valves is very clear owing to the long spaces in between the turns. The anterior five cones point anteriorly, while the posterior point backward.

The number of valvular turns is increased in *Aëtobatus narinari* to 40 turns, but reaches its maximum in *Mobula kühlii*, where there are 54 very thin turns. In these two species, the turns of the valve are not rolled to a central axis, but are in the form of separate rings (Text-fig. 9) beginning just posterior to the end of the duodenum and attached to the walls of the intestine all the way round. The central free edge of the rings in both species is produced into clear processes, while the whole surface is covered by small papillae in *A. narinari* and by microscopic villi in *M. kühlii*.

The valvular fold in *Rhynchobatus djiddensis* (Pl. IV, Fig. 3) has a special shape which differs from that of all the above-described species. In this species a thick fold originates just posterior to the pyloric valve and forms an axis which winds spirally posteriorly forming 16 turns. The distance between succeeding turns decreases gradually posteriorly, and accordingly the axis is more clearly seen between the anterior turns. In addition to this valve, independent transverse folds project from the wall of the intestine and are arranged as follows: In the anterior-most part where the central axis originates anterior to the first turn, and on either side, five incomplete ring-like ridges project from the ventrolateral walls of the intestine perpendicularly to the long axis. These incomplete rings are followed by complete annular rings of which the first thirteen or fourteen occur anterior to the first turn of the spiral fold, the rest occur between the successive turns. These rings project from the walls of the intestine and gradually decrease in width and number rearwards. Thus 13-11, 10-8, 8, 7, 7, 7-6, 6, 5, 4, 3, 2 and 1 have been counted between the anterior 13 turns of the spiral valves respectively. No such rings occur between the last turns of the spiral valve. The whole surface of the spiral valve as well as the rings is covered with minute villi.

So far as we are aware no description has, as yet been given of such a type of intestinal valve, and it is proposed to call it the spiro-annular type.

*Rhina ancylostoma* is the only other batoid which was found to possess such a type of spiro-annular valve but the number of the valve spiral turns as well as the separate rings is somewhat reduced as compared with *Rhynchobatus*. Thus, the spiral valve has only 10 turns as compared with 16 in *Rhynchobatus*, and the annular rings are distributed as such: 17 rings occur anterior to the first turn of the spiral fold, and 12, 12, 12, 10, 8, 6, 5, 5, 3 were counted between the ten turns of the spiral valve respectively.

In the elasmobranchs examined, in this work, the scroll type of intestine was met with in the Carcharhinidae and the Sphyrnidae. The spiral type was found in the Alopiidae, Orectolobidae, Isuridae, Triakidae, Rhinobatidae, Torpedinidae and Dasyatidae. The Aëtobatidae and Mobulidae have the ring type. The fourth spiro-annular type is met with only in the Rhynchobatidae.

#### C.—Colon and rectum :

The valvular intestine narrows down posteriorly, and becomes slightly constricted, leading into a short muscular colon which externally appears somewhat bulbous (Text-fig. 4). Internally (Text-fig. 7), the lining is thrown into longitudinal irregular folds of various thicknesses.

Following the colon is the last part of the intestine which is the short thin rectum. In both non-valvular portions, colon and rectum, the villi covering the valvular intestine are absent and the lining is smooth. Internally, the opening of the rectal gland forms a line of demarcation between the colon and the rectum.

#### Rectal gland :

The rectum carries the rectal gland characteristic of elasmobranchs. The gland (Text-figs. 1, 3, 4 and 8) is generally finger-shaped and possesses a central canal-like cavity, and is attached to the dorsal body wall by means of the posterior mesentery. It ties on the left side of the rectum with the apex pointing towards the axis of the body, and the stalk towards the rectum where it extends usually anteriorly on its left side to open between it and the colon. The gland varies in size from a small structure to a long one. Among the species examined, the rectal gland reaches its maximum length in *G. cuvier* where it has a rounded apex and posteriorly towards the rectum by means of a short stalk passes shortly anteriorly to open internally on the left dorsal wall proximal to the markedly short colon. *Nebrius concolor* has a characteristically short, wide and thick muscular rectal gland that passes directly to open between the colon and the rectum. *Rhinobatos halavi* possesses a relatively long and slender rectal gland, in contradistinction with *Rhynchobatus djiddensis* where the gland is relatively thick and short. *Teniura*, *Mobula*, and *Aëtobatus* possess slender small rectal glands.

Externally, the rectal gland is covered by a whitish muscular coat, below which is a pinkish glandular tissue, which incloses a lumen that starts anteriorly and passes caudally, becoming narrower at the same time until it reaches the dorsal wall of the rectum where it curves anteriorly to open between the rectum and the colon.

Although the rectal gland has been studied in a great number of elasmobranchs, (e.g. Howes, 1890, Hoskins, 1917, and Doris 1925), yet its function is still not clear.

#### D.—Cloaca

This is a conical chamber (Pl. II, Fig. 4) lying posterior to the pelvic girdle between the bases of pelvic fins, with the apex towards the tail. Into this chamber, which leads to the outside by the cloacal aperture, empty the digestive tract and the urinogenital system. On the latero-posterior sides of the cloaca two papillae are usually found, one on each side, and these are perforated by the abdominal pores which put the abdominal cavity into connection with the outside.

#### Glands of the Digestive Tract.

Associated with the digestive tract are the liver, the pancreas and the rectal gland which shed their secretions into the alimentary canal by means of their ducts. The spleen is a ductless organ also connected with the digestive system, but its origin is not clear.

#### The liver:

The liver is a brownish organ which extends along the abdominal cavity just posterior to the transverse septum and covers the greater part of the viscera. It hangs anteriorly by means of the falciform ligament. It differs in general form in sharks and rays.

In *Galeocerdo cuvier* (Text-fig. 1) as well as most sharks (Pl. I, Fig. 3) it is well developed consisting of two long lobes connected anteriorly by a narrow mesenteric ligament. Both lobes extend backwards along the entire length of the abdominal cavity, completely enclosing the alimentary canal between them. A thin-walled rounded gall-bladder is embedded in the anterior portion of the left lobe and drains by a tubular slender ductus choledochus which passes to the dorsal proximal part of the intestine (the duodenum) to the right side of the origin of the intestinal valvular fold (Text-fig. 2). Of all the examined species, the liver of the tiger-shark yielded relatively the largest quantity of oil, the liver weight was about 17% of the body weight, and each kilogram gave 444 gm. of oil (of clear fatty nature and yellowish colour).

*Nebrius concolor* has a massive liver, the two lobes of which are connected in the middle, nearly from their anterior end backwards to about half their length and only two deep incisions one dorsal and the other ventral are left to indicate the double nature of this part. The left lobe is more voluminous than the right

and is broader anteriorly. The weight of the liver is about 18% of the body weight, but has a relatively low oil content as each kilogram of liver gave 350 gm. of oil, of reddish colour. The gall-bladder is embedded in the inner angle of the left lobe as a spherical sac drained by the ductus choledochus which passes backwards to the dorsal side of the duodenum where it opens, at the anteriormost portion hidden below the anterior origin of the valvular fold.

In *Taniura lymma*, the liver (Text-fig. 4) differs in shape from the above-described sharks, being shorter and broader. It consists of two lobes of nearly equal length, but the left is broader and more voluminous than the right. Both lobes are moulded to the shape of the short abdominal cavity and the viscera, of which they enclose the largest part. The two lobes are connected anteriorly, the connection being direct along the vertebral side, where only a short superficial fission can be seen, and indirect dorsally through a small connecting isthmus. The gall-bladder is rounded and completely hidden in the isthmus somewhat nearer to the right lobe. From the posterior portion of the gall-bladder, originates a comparatively wide cystic duct which soon receives a main hepatic duct from the right liver lobe, and then extends leftwards receiving a number of hepatic ductules from the right lobe and, after a little, the cystic duct receives a left hepatic duct from the left liver lobe. Now the ductus choledochus passes caudally below the left branches of the hepatic portal vein—which enters the left liver lobe at this region—then swings rightwards crossing the hepatic vein ventrally, and then backwards to the duodenum, extending a little in its wall and then penetrates its latero-dorsal wall and opens near the right side of the valvular fold (Text-fig. 6). The liver weighs 5% of the body weight.

The liver of *Aëtobatus narinari* and *Mobula kühlii* resembles that of *T. lymma*, but it is relatively largest in *A. narinari* where its average weight is 5.2% of the body weight. The gall-bladder is markedly large in *A. narinari*, ranging from 5 to 10 cm. in diameter and is embedded in the right lobe. The bile duct passes to the most anterior part of the duodenum where it opens internally on the edge of the small protruding ridge on the right dorsal corner (Pl. III, Fig. 2).

The bile duct in *Mobula* (Text-figs. 8 and 9), passes directly to open posteriorly below the bursa entiana on the dorsal side of the duodenum, at the middle of its anteriormost portion.

In the transitional forms, *Rhynchobatus djiddensis* and *Rhinobatos halavi*, the liver consists of three lobes of which the middle is shorter than the equal lateral lobes. All are connected anteriorly and each forms a nearly triangular mass. The gall-bladder is rounded and inserted in the angle of the right lobe. The liver is relatively smaller than in other species described here, as in *R. djiddensis* it is 3.7% of the body weight and in *R. halavi* it is only 2%.

In *R. djiddensis* and *R. halavi*, the bile-duct opens, as in most of the described species, into the duodenum at the right dorsal side of the valvular fold.



The gall-bladder in *Alopias vulpinus*, is unique among all the above described species being long and slender. It attains a length of 10 cm. and is only 2.5 cm. in diameter in a 3 metres long specimen.

#### The pancreas :

Although the pancreas differs slightly in general form, from one species to another, yet in all the examined species—as is usual for elasmobranchs—it is a cream-coloured organ formed of two well-developed lobes ; a clear compact ventral lobe, resting terminally on the ventral surface of the proximal part of the valvular intestine ; and a dorsal lobe attached to the former by a short limb, and hidden in a pocket formed by the junction of the suspensory ligament of the spiral intestine and the gastro-choleodochic omentum (Text-fig. 5). Both lobes empty by a single common duct which emerges from the ventral lobe and passes to open in the dorsal wall of the proximal part of the duodenum.

In *Galeocерdo cuvier* (Text-fig. 1), both lobes of the pancreas are long and narrowly flattened, but the ventral is broader at its terminal portion. The pancreatic duct opens on the dorsal side of the duodenum slightly posterior to the bile duct, on the left side (Text-fig. 2).

*Nebrius concolor* has nearly triangular and equal pancreatic lobes. The pancreatic duct opens in the middle dorsal side of the duodenum just below the origin of the valvular fold.

*Tæniura lymma* (Text-figs. 4 and 5) possesses a relatively small pancreas, its ventral lobe is kidney-shaped while the dorsal is nearly oval and thicker.

The pancreatic duct opens on the dorsal side of the duodenum at the same level as the opening of the bile duct, but is hidden under the valvular fold.

The largest pancreas is found in *Aëtobatus narinari*, in which the dorsal lobe is oblong and the ventral is discoid and massive (Pl. II, Fig. 4). The pancreatic duct opens dorsally in the middle of the narrow lumen preceding the duodenum.

*Mobula kühlii* has a bulky and nearly triangular dorsal lobe and a larger flattened irregular ventral one. The pancreatic duct opens dorsally at the end of the duodenum, far away from the ductus choledochus as described before (Text-fig. 9).

The smallest pancreas, relative to the size of the body, is that of *R. halavi* which possesses two small triangular lobes with irregular margins. The pancreatic ducts open dorsally on the left side of the bile duct.

*R. djiddensis* has a massive V-shaped pancreas, with its duct opening on the dorsal side below the tip of the valvular fold of the intestine.

#### The Spleen :

In *Galeocерdo cuvier*, the spleen (Text. fig. 1) is formed of a long reddish lobe, broader and strongly curved at the lower part which lies on the right side of the caecum and continuing as a gradually narrowing lobe parallel to the pyloric limb of the stomach and ending a short distance before the end of the latter.

In *Nebrius concolor*, the spleen (Text-fig. 3) is broader and thicker than in *G. cuvier*, and tends to divide into two lobes, a shorter thicker and broader lobe, with irregular margins lying at the outer curvature of the stomach and a long narrower irregular lobe which extends parallel to the pyloric limb and reaches the proximal portion of the duodenum.

In the examined batoids, *Tæniura lymma* (Text-fig. 4), *Aëtobatus narinari*, *Mobula kühlii* (Text-fig. 8), *Rhinobatos halavi* and *Rhynchobatus djiddensis*, the spleen, as in most rays, occurs in the region of the lesser curvature of the stomach as a compact oval or rounded organ, sometimes with highly lobate margins.

#### Mesenteries and Topography of the Digestive Viscera :

When the abdomen is opened, the liver is seen to occupy the greater part of the space and agrees in general shape with that of the abdominal cavity ; thus in sharks (Pl. I, Fig. 3) where the abdominal cavity is long, the liver lobes are long and extend from the transverse septum anteriorly to the posterior end of the abdominal cavity. In rays, where the abdominal cavity is nearly rounded and shorter, the liver is moulded accordingly and is thus plumpy and short.

When the liver is removed (Pl. II, Fig. 4), the alimentary canal is disclosed and the oesophagus, which follows the pharynx, is seen leading to the left side to the stomach. This is mostly J-shaped, (U-shaped, in *Galeocерdo cuvier*) and its longer left limb curves with the left side of the abdomen then leads rightwards and upwards to the shorter pyloric limb. This extends to the middle of the abdominal cavity (or somewhat beyond in *G. cuvier*) and is followed by the short duodenum (or long and convoluted, only in *Mobula kühlii*) which in turn, leads to the valvular intestine that occupies the right posterior two thirds of the abdominal cavity, uniting at its end with the rectum which ends in the cloaca.

The different organs of the digestive tract are held together as well as to the dorsal abdominal wall by the mesenteries, which are more complicated in *G. cuvier* than in the shark *N. concolor* and the batoids *T. lymma*, *A. narinari*, *M. kühlii*, *Rhynchobatus djiddensis* and *Rhinobatos halavi*.

In *G. cuvier* (Text-fig. 1) as in most sharks, the dorsal mesenteries arise in two sections, from the dorsal body wall, an anterior and a posterior. The anterior mesentery is rather complicated and forms a sort of envelop to the digestive tract. A right fold of this mesentery passes along the mid-dorsal line from below the liver backwards to suspend the spiral intestine, *i. e.* forming the suspensory ligament. A left fold of the mesentery originates opposite to the right fold (and firmly attached to it along the dorsal line of origin) and extends from the mid-dorsal line to the dorsal side of the oesophagus and stomach. Parts of this fold extend between the pyloric stomach and spleen, forming the gastro-splenic omentum ; another ligament extends between the pyloric limb and the two pancreatic lobes, representing the gastro-pancreatic omentum.



A third median fold of mesentery extends from the mid-dorsal line—just at the origin of the right mesenteric part—across to the oesophagus and down the lesser curvature of the stomach to the proximal portion of the duodenum.

The posterior mesentery is simple and extends from the mid-dorsal line to the rectal gland, constituting the meso-rectum.

The mesentery in *Teniura lymma*, as well as in other batoids described here, is formed of a thick dorsal fold arising from the dorsal midline below the oesophagus (Text-fig. 5) and extending to the right side to suspend the intestine and is known as the suspensory ligament. From the original fold extends another ligament to the ventral left side to suspend the stomach at its lesser curvature forming the mesogastrium. This continues upwards with the part of mesentery which suspends the hepatic portal vein and the ductus choledochus and the two form a gastro-cholechoctic omentum (Text-figs. 4 and 5) which extends rightwards to unite with the suspensory ligament of the intestine. The dorsal lobe of the pancreas is enclosed at the junction between the suspensory ligament of the spiral intestine and the gastro-cholechoctic omentum. From the dorsal midline below the oesophagus, arises another thick mesenteric fold which suspends the oesophagus and extends rightwards to join the gastro-cholechoctic omentum. A gastro-splenic ligament extends between the spleen and the cardiac limb. Another part of the mesentery extends from the spleen rightwards and upwards to the ventral side to the proximal portion of the duodenum. This ligament coats the ventral lobe of the pancreas and is thus called the spleno-pancreatic ligament. Along the greater curvature of the stomach, passes a thick mesenteric fold, which proceeds cephalad to the duodenum as a gastro-duodenal omentum, and joins the spleno-pancreatic ligament. Posteriorly, the rectal gland is attached to the dorsal body wall by the mesorectum.

## 2. Circulatory System

It is suggested to deal here only with the heart, the coronary circulation and the major vessels.

### A.—The heart :

This is a purplish-red organ which lies in the pericardial cavity, in the posterior interbranchial region, in front of the sternal symphysis of the pectoral arch. As in all elasmobranchs, the heart is formed of the usual four chambers viz. the sinus venosus, the auricle, the ventricle and the conus arteriosus.

### The sinus venosus :

This lies dorsal to the ventricle, as a triangular thin-walled sac with the apex leading to the auricle and the base directed posteriorly. Dorsally, the sinus venosus

is fused to the posterior part of the roof of the pericardial cavity and laterally, each angle of the base of the triangle extends to one side (one right and the other left) as the Cuvierian duct. The internal surface of the sinus venosus is smooth, and its cavity is connected to that of the auricle (at the apex of the triangle) by a sinu-auricular aperture, which is guarded by two sinu-auricular valves. These are smooth, oblique flaps projecting from the auricle to the sinus venosus and allow the blood to flow from the sinus venosus to the auricle ; while preventing the back-flow from the auricle (Pl. V, Fig. 3).

### The auricle :

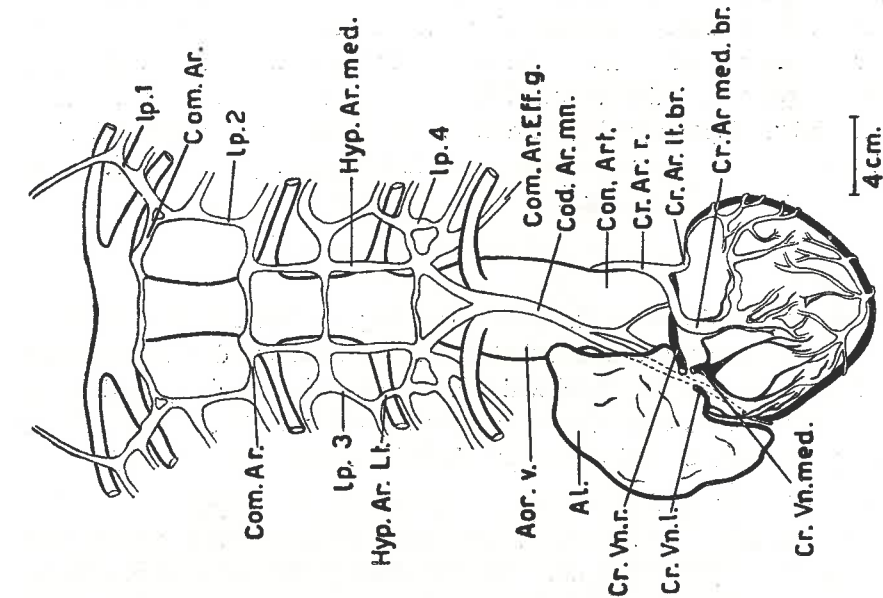
In all the examined species, the auricle is a large sac-like structure which lies dorsal to the ventricle ; and is attached at its base to the antero-dorsal left surface of the latter (Text-figs. 10, 13, 17, 20 and 23). The auricle extends upwards to lie dorsal to the proximal basal portion of the conus arteriosus. When full of blood, the auricle appears as a distended bag with the left side larger than the right.

The auricle is thin and differs in relative thickness from one species to another. It is formed internally of anastomosing thin cardiac muscles, which give the wall a spongy appearance (Pl. V, Fig. 3). An oval opening, the auriculo-ventricular opening, leads from the left side of the base of the auricle to the ventricle. This opening is guarded by an auriculo-ventricular valve. Daniel (1934, p. 171) stated that this valve consists, in elasmobranchs, of two pocket-like flaps. However, in all the sharks and batoids examined here, viz. *Galeocерdo cuvier*, *Nebrius concolor*, *Carcharhinus melanopterus*, *C. maculipinnis* and *C. sorrah*, *Teniura lymma*, *Aëtobatus narinari*, *Dasyatis uarnak*, *Rhinobatos halavi* and *Rhynchobatus djiddensis*, the auriculo-ventricular valve was found to consist of four pocket-like flaps (e. g. Pl. V, Fig. 3). Of these, the dorsal and ventral flaps are larger than the two lateral. Such a condition was discovered in *Cephaloptera giornae* by Mazza (1891) who considered the small lateral cusps as accessory ones, as well as in *Manta ehrenbergi* by Gohar and Bayoumi (1959). The concavities of the auriculo-ventricular valves are directed towards the ventricle, so that they allow the blood to pass only from the auricle to the ventricle but not in the opposite direction.

### The ventricle :

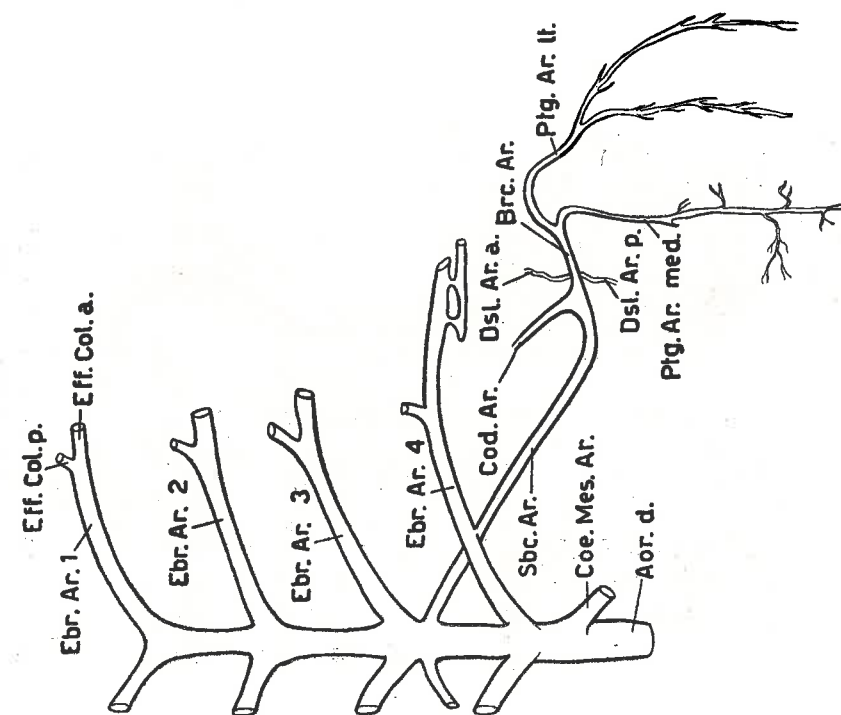
This is a thick-walled structure occupying the posterior portion of the pericardial cavity.

In *Galeocерdo cuvier*, the ventricle (Text-fig. 10) is somewhat pyramidal with a convex base, while in *N. concolor* it is relatively small and pyramidal, the posterior face being fairly straight (Text-fig. 13). In *T. lymma* and *A. narinari* (Text-figs. 17 and 20), the ventricle is globular, but in *R. halavi* (Text-fig. 23) and *Rhynchobatus djiddensis*, it is somewhat flattened and broader.

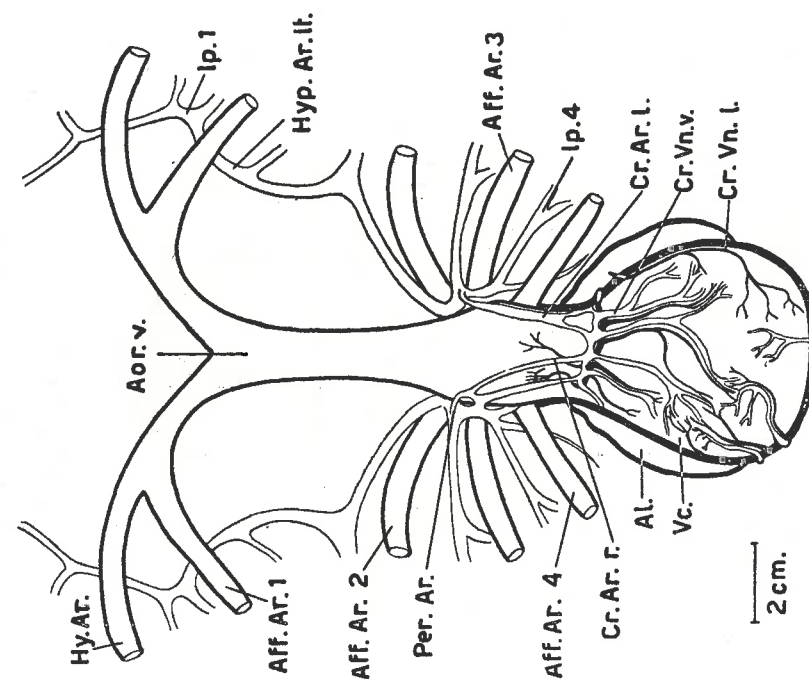


Text-fig. 10 : *Galeocerdo cuvier*, ventral view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypobranchial arteries.

Text-fig. 11 : *Galeocerdo cuvier*, dorsal view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypobranchial arteries.

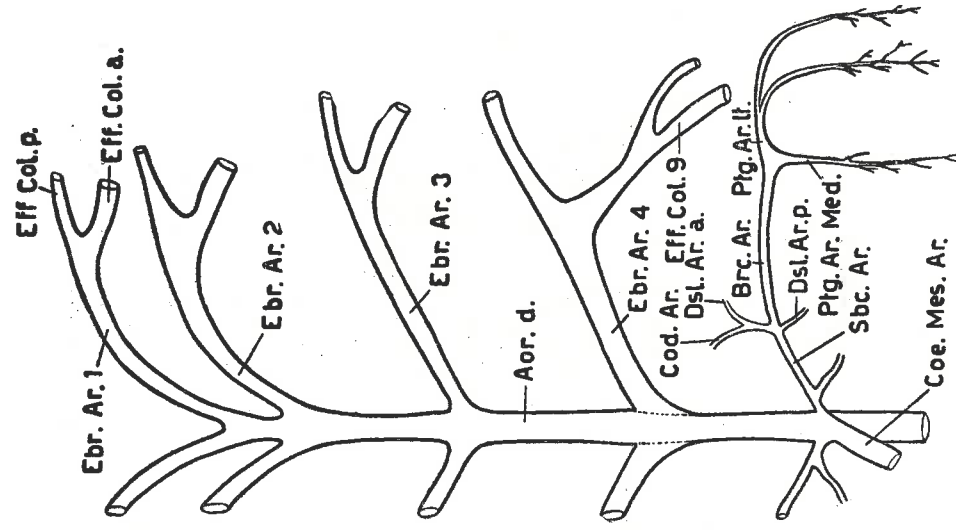


Text-fig. 12 : *Galeocerdo cuvier*, efferent branchial arteries, together with dorsal aorta and some of its branches.

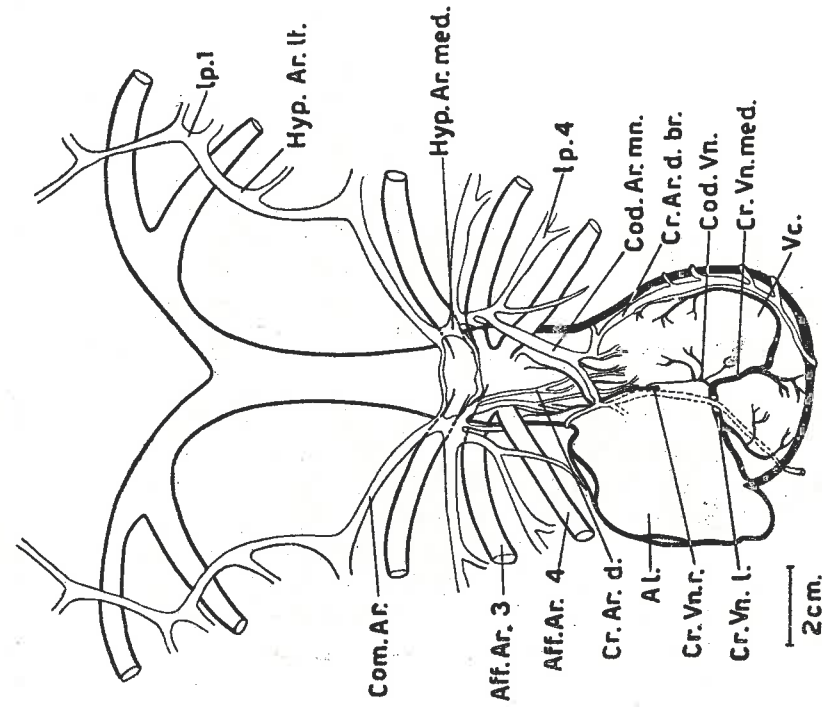


Text-fig. 13 : *Nebrinus concolor*, ventral view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypobranchial arteries.

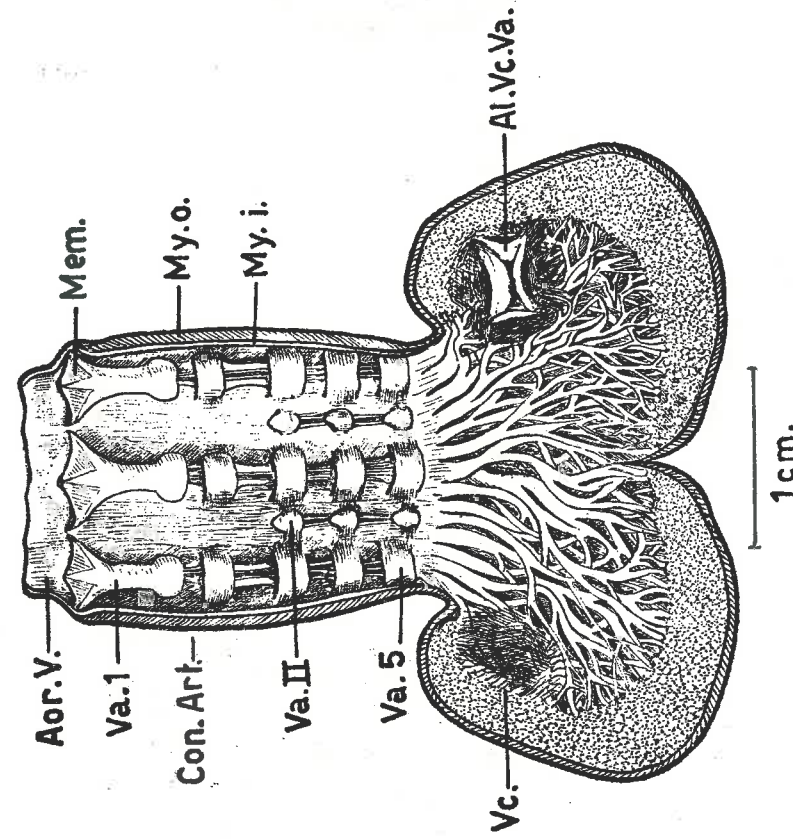




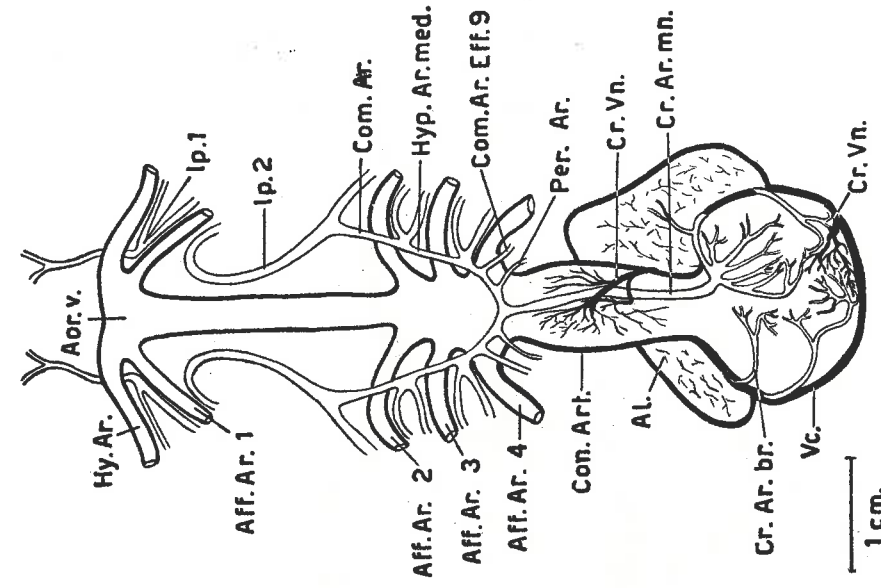
Text-fig. 15 : *Nebrius concolor*, efferent branchial arteries, together with dorsal aorta and some of its branches.



Text-fig. 14 : *Nebrius concolor*, dorsal view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypobranchial arteries.

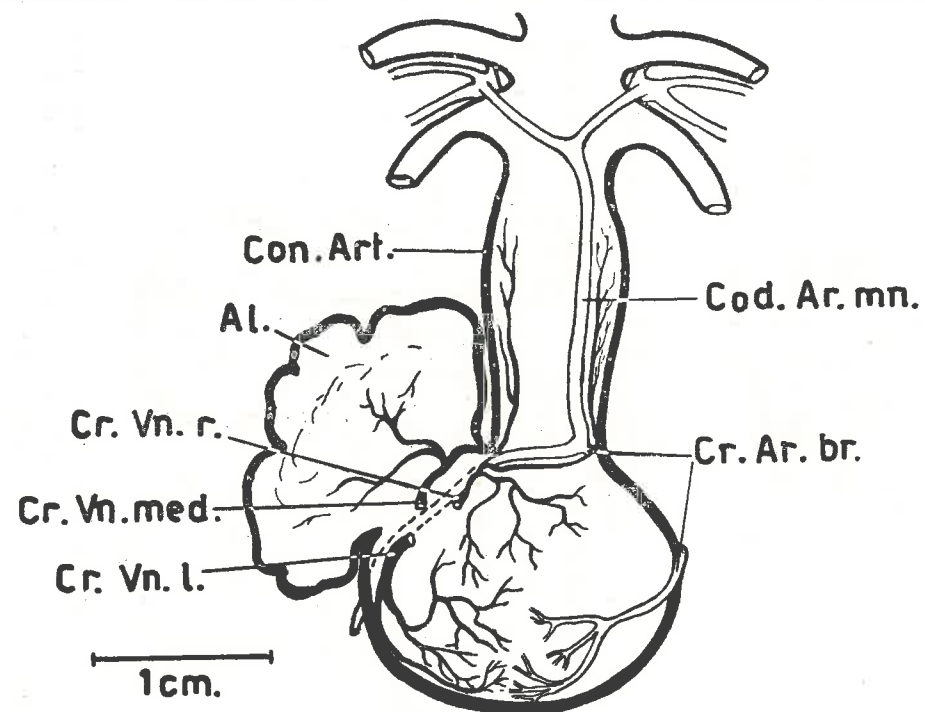
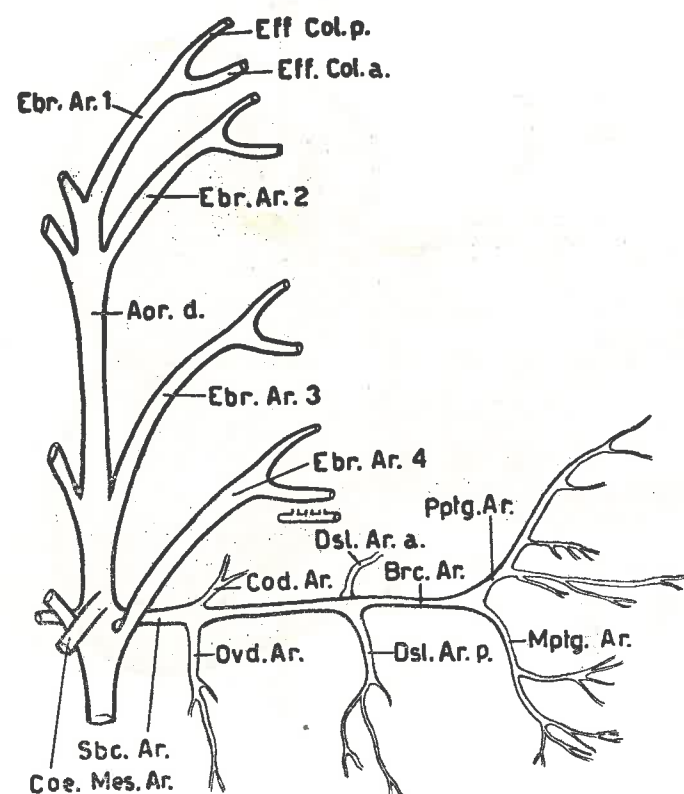
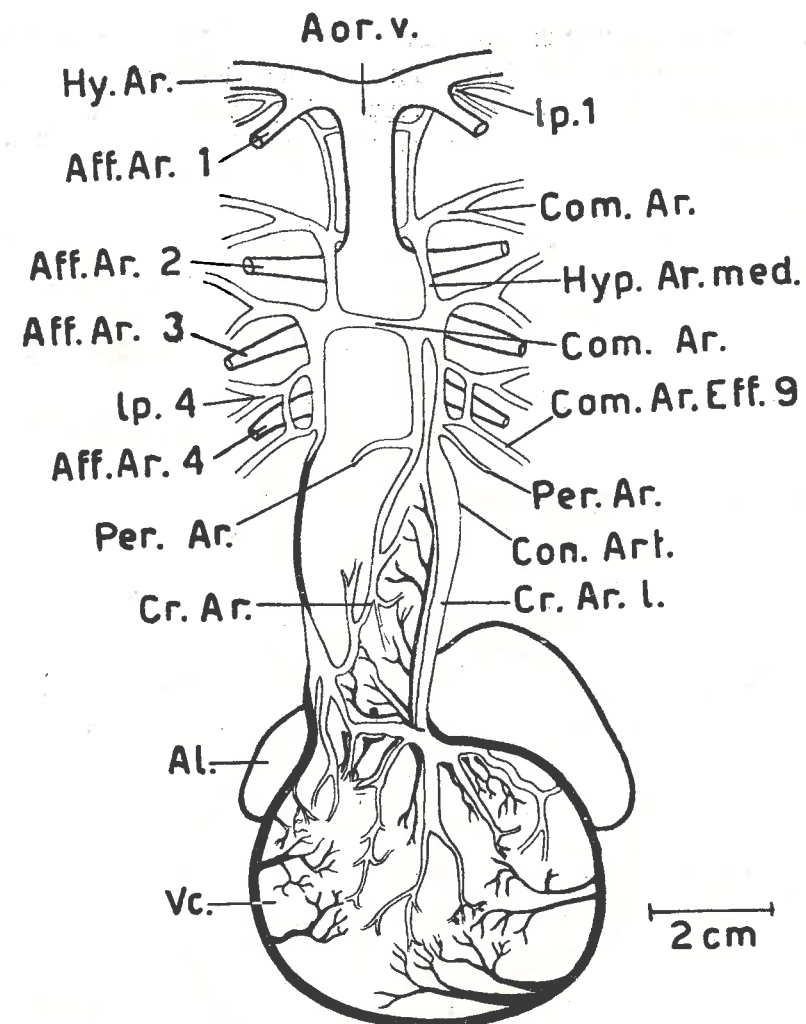


Text-fig. 16 : *Taeniura lymna*, conus arteriosus and ventricle opened from ventro-lateral side; walls stretched to show the three rows of valves of conus arteriosus (dorsal row of valves in middle and two ventro-lateral rows at sides) and internal structure of ventricle.



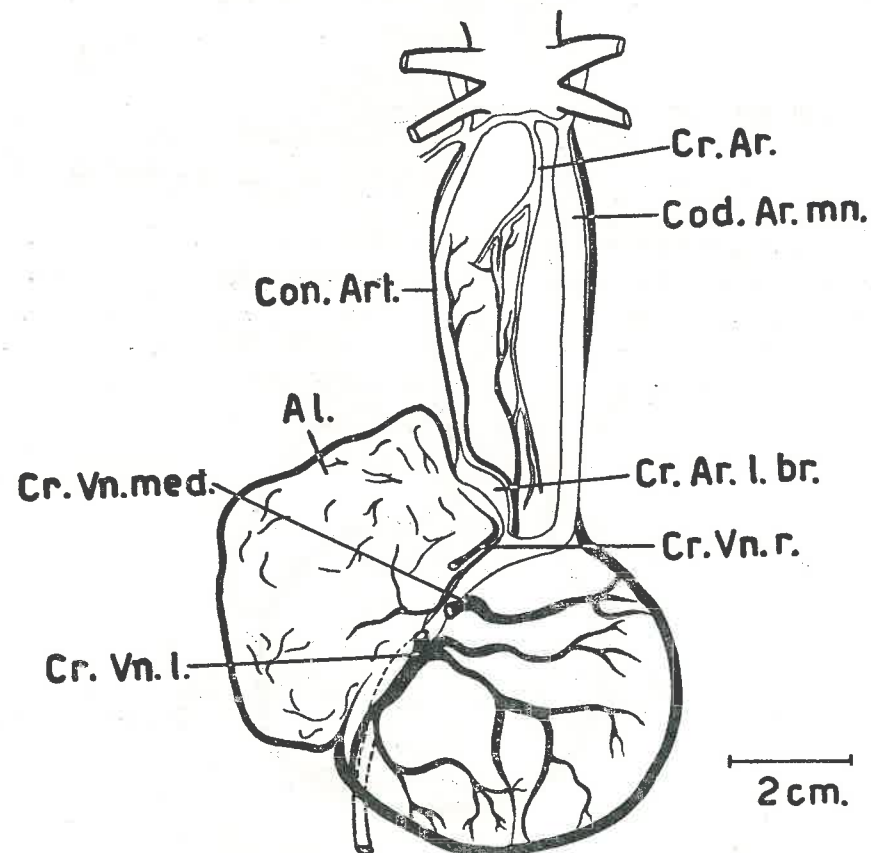
Text-fig. 17 : *Taeniura lymna*, ventral view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypobranchial arteries.



Text-fig. 18 : *Taeniura lymma*, dorsal view of heart with coronay blood vessels.Text-fig. 19 : *Taeniura lymma*, efferent branchial arteries together with dorsal aorta and some of its branches.Text-fig. 20 : *Aetobatus narinari*, ventral view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypo-branchial arteries.

The ventricle, in contrast to the thin-walled atrium, has very thick walls and a narrow cavity. The myocardial coat is thick and is formed of a single layer of muscles, which attains its maximum thickness in the shark *G. cuvier* (Pl. V, fig. 1), where in a specimen 321 cm. long it reached 3 cm. all over the posterior walls getting thinner near the base of the conus arteriosus. The myocardium is also relatively markedly thick in *N. concolor* (Pl. V, Fig. 2), maximum thickness 2.5 cm. in a specimen 224 cm. long ; but somewhat less thick in *A. narinari* (Pl. V, Fig. 4). In *T. lymma*, *R. halavi* and *R. djiddensis* (Text-fig. 16, Pl. VI, Figs. 2 and 1 respectively) this

myocardial layer is relatively thinner. The muscular wall of the ventricle is thrown into numerous irregular trabeculae, giving the inside of the ventricle a coarse spongy appearance. The valves are also supported by chordae tendinae, stretched from the walls of the ventricle to the auriculo-ventricular valves (Pl. VI, Fig. 2).



Text-fig. 21 : *Aetobatus narinari*, dorsal view of heart with coronary blood vessels.

#### The conus arteriosus :

This is an elongated tube-like muscular organ which follows the ventricle, and leads to the ventral aorta. It is short in many Selachii such as *G. cuvier* and *N. concolor* (Pl. V, Figs. 1 & 2) ; while relatively long in batoids such as *T. lymna*, *A. narinari*, *Rhinobatos halavi* and *Rhynchobatus djiddensis* (Text-fig. 16, Pl. V, Fig. 4 and Pl. VI, Figs. 2 and 1 respectively).

Internally, the muscular wall of the conus arteriosus is differentiated into two layers : an outer myocardial layer, which extends as a continuation of the same layer in the ventricle, and ends anteriorly at, or slightly before, the beginning of the ventral aorta, and an inner myocardial layer which is thin and extends from the base of the conus arteriosus upwards along and continues anteriorly with the walls of the ventral aorta. Such muscular walls of the conus serve to keep the blood flowing from the conus to the aorta at a more constant pressure.

The endocardiac lining of the conus arteriosus extends inwards to form the semilunar valves which are arranged in three longitudinal rows, one dorsal and two latero-ventral. These form a triangle around the internal circumference of the walls, and so the lumen of the conus arteriosus is narrowed into a conical cavity. These valves, prevent the back-flow of blood into the ventricle ; and they are characteristic for elasmobranchs, and had been previously described in many species by certain authors among whom may be mentioned Garman (1885 & 1913), Parson (1930), Day (1934), White (1936, 37), Ishiyama (1958) and Gohar and Bayoumi (1959).

In *G. cuvier* (Pl. V, Fig. 1) each of the three longitudinal rows consists of three cusps (in all the examined specimens). The anteriormost set is of much larger cusps than those of the following two series. Each cusp of the first set is a deep, pocket-like membrane fold, which has most of the anterior part related to the ventral aorta rather than to the conus arteriosus. The middle part of the valve is somewhat thickened and points anteriorly ; while the lateral sides are thin membranes connected to the other two cusps. Each of these cusps is attached internally at the base to the wall of the conus arteriosus by short thin chordae tendinae, and externally at the posterior base to the internal side of the following cusp of the same row by numerous chordae tendinae.

The valves of the second set are much smaller but of relatively thicker membranes than the preceding. The pocket of the valve is directed anteriorly, and each valve is connected at its lateral walls to the conus arteriosus by short chordae tendinae. Also the posterior margin of the valves is connected by similar chordae—though longer and more numerous—to the internal walls of the following posterior cusp.

The valves of the third, (last) set are similar to those of the second set.

A pair of very small accessory valves occurs posteriorly between each two succeeding longitudinal rows (the dorsal and ventro-lateral). These small valves are of the same pocket-shape as the neighbouring large ones ; and each is attached by short chordae tendinae to the walls of the conus.



*Nebrius concolor* possesses a smaller number of valves ; as only two cusps are found in each longitudinal row (Pl. V, Fig. 2) the valves have only the antero-lateral portions membranous, and the rest is greatly thickened especially posteriorly. A small accessory valve occurs posteriorly between each two main valves. In a single specimen an accessory row, formed of two cusps, was met with parallel to, and in between, two main rows ; and the accessory valves were only slightly smaller than those of the main rows.

White (1937, p. 91 ; Fig. 63, after Garman) stated that *Aëtobatus narinari* had only five valves in each row which she clearly illustrated. In our specimens, however, the number is increased as there are eight valves in each row (Pl. V, Fig. 4).

As usual, the first cusp of each row is the largest, and is here greatly thickened, as the membranous portion is restricted to small lateral parts, while the rest of the pocket projects as a thick ridge. This is followed posteriorly by seven valves which are completely membranous and much smaller. Two or three accessory rows (each 2-3 very small cusps) occur rearwards between the main rows. The wall of the conus is marked by numerous thin cord-like ridges between the longitudinal rows.

*Taniura lymma* (Text-fig. 16) possesses five cusps in each main row and two or three accessory rows, each of three cusps. The valves are very small and membranous.

Both *Rhynchobatus djiddensis* (Pl. VI., Fig. 1) and *Rhinobatos halavi* (Pl. VI, Fig. 2) possess a similar number of valves, five in each row. The lumen of the conus is much reduced, and the lining is thrown into three high elevated ridges extending end to end, and each ridge is free, only anteriorly, to form the pocket of the first large valve. The following cusps are membranous and attached to the ridge, and they become gradually smaller posteriorly. Accessory valves are arranged in one or two rows (of 2-3 cusps), but are sometimes dispersed singly between the main rows.

The number of the valves of the conus arteriosus was also examined in certain Selachii as well as batoids, besides the above described species. There are only two in the sharks *Carcharhinus melanopterus*, *C. maculipinnis*, *C. sorrah*, *C. albimarginatus* (all from the Carcharhinidae) ; and in *Stegostoma fasciatum* (Orectolobidae).

In *Carcharhinus longimanus*, *Scoliodon walbeehmi*, *S. palasorrah*, *Triaenodon obesus*, *Heterogaleus ghardagensis* (all from the Carcharhinidae) and *Mustelus canis* (Triakidae) three valves occur in each row.

The transitional form of batoids, *Rhina squatina* (Rhynchobatidae), possesses five valves.

The rays *Dasyatis uarnak* and *D. sephen* (Dasyatidae) each has six valves in a row ; while *Torpedo panthera* (Torpedinidae) possesses only four cusps.

#### B.—Ventral Aorta and Afferent Branchial Arteries :

As in all elasmobranchs, the ventral aorta in the species examined (Text-figs. 10, 13, 17, 20 and 23) continues from the conus arteriosus anteriorly as a tube which passes along the floor of the pharynx ; giving off paired branches, the afferent arteries, which distribute the blood to the gills for oxygenation.

The ventral aorta ends forward at the region of the mandibular symphysis, where it divides into two trunks, a right and a left. Each of these divides in turn into two arteries, the first supplies the hyoid arch and is known as the hyoid ; and the second supplies the first gill-arch as a first afferent branchial artery.

The second, third and fourth afferent branchial arteries arise separately from the ventral aorta in *G. cuvier* (Text-fig. 10) as well as in the rays *T. lymma* (Text-fig. 17) *A. narinari*, *Dasyatis uarnak* and *D. sephen*. This is not in agreement with Daniel's statement (1934, p. 172-73) that in rays in general, only two stems leave the ventral aorta, the first divides to supply the hyoid and the first gill-arch ; while the second gives branches to the second, third and fourth gill-arches.

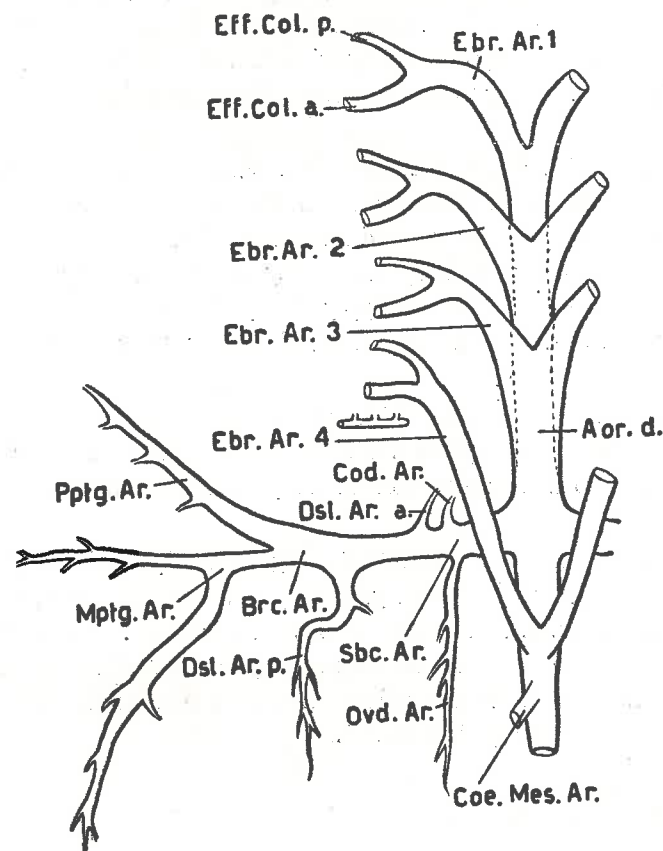
In the shark *Nebrius concolor* (Text-fig. 14), the second afferent vessel arises separately, while the last two (third and fourth) arise from a short common trunk. Daniel (1934) described a similar case in *Dasyatis dipterura*.

In the batoids, *Rhinobatos halavi* (Text-fig. 23), *Rhynchobatus djiddensis* and *Rhina ancylostoma*, the ventral aorta gives rise to a common trunk which divides into the second, third and fourth afferent branchial arteries. Each afferent artery continues around the base of the cartilaginous gill-arch in front of the branchial rays, where it gives rise to smaller afferent arterioles both to the anterior and the posterior filaments of every holobranch.

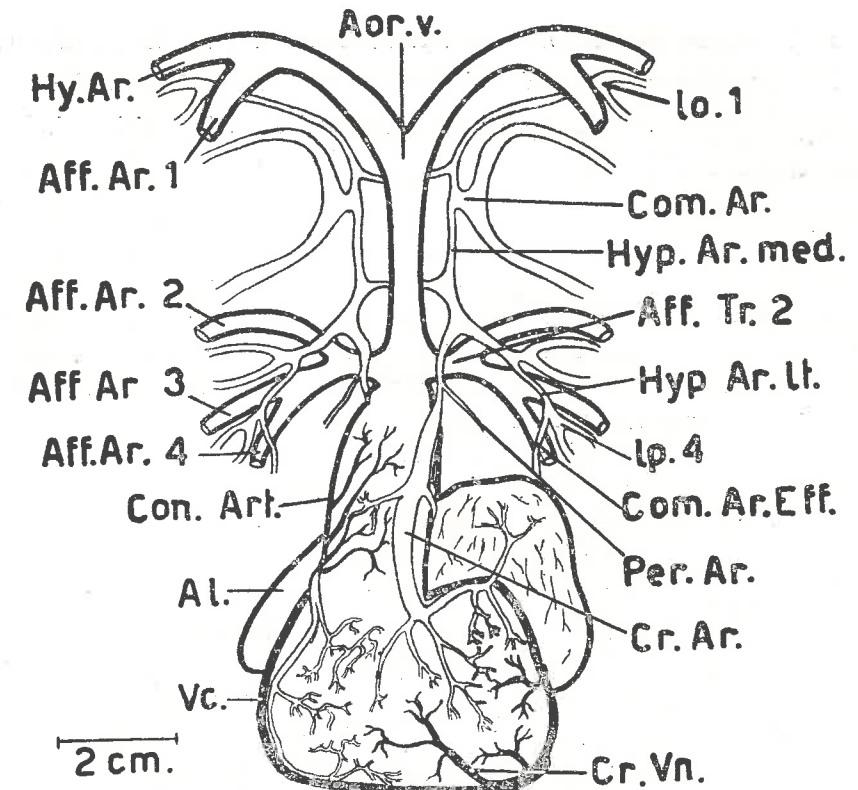
#### C.—Efferent Branchial Arteries :

The oxygenated blood is sent down the gill filaments into efferent collectors (branchial arteries) lying at the bases, and corresponding to the number, of the demibranchs. Thus, nine efferent collectors are present.

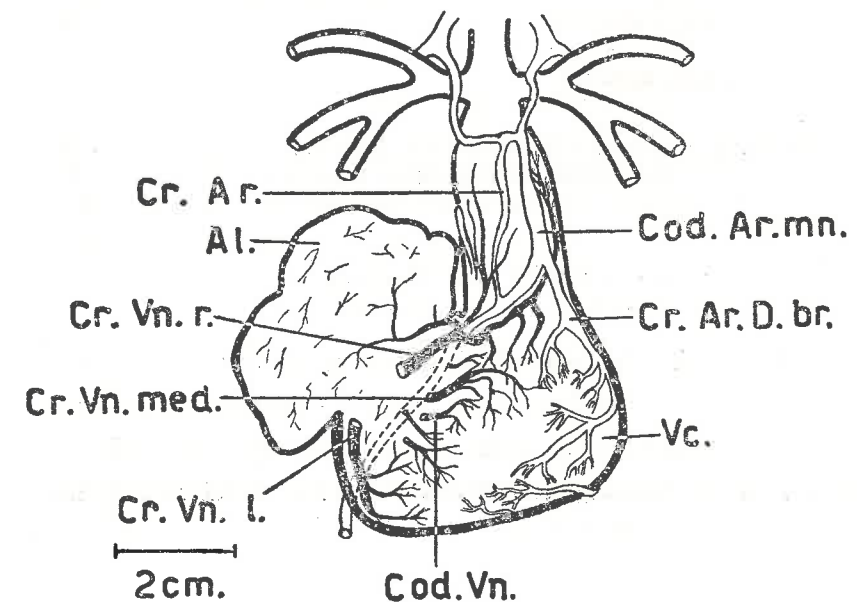
In *G. cuvier*, *N. concolor*, *T. lynna*, *A. narinari*, *R. halavi*, *Rhynchobatus djiddensis* and *Rhina ancylostoma*, conditions in this respect agree with the general rule for elasmobranchs, thus four complete loops are formed from eight efferent collectors, and surround the first four gill-clefts. The efferent collector which forms the anterior part of the loop, however, is a posterior efferent collector, as it drains the posterior demibranch of a whole gill; and the efferent collector, posterior to the cleft, is the anterior efferent collector of the following gill. The last gill-cleft (having only an anterior demibranch) has an efferent artery on its anterior side only (Text-figs. 12, 15, 19, 22 & 25). All the above-mentioned species, except *N. concolor*, agree with the general plan of elasmobranchs having the last posterior efferent collector separated dorsally from the anterior collector, in front, to which blood flows by means of cross trunks.



Text-fig. 22 : *Aetobatus narinari*, efferent branchial arteries together with dorsal aorta and some of its branches.



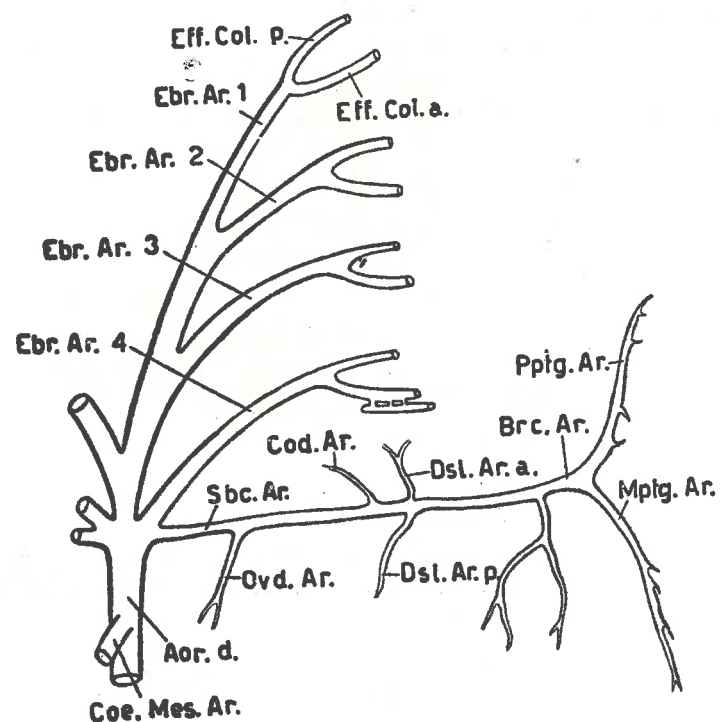
Text-fig. 23 : *Rhinobatos halavi*, ventral view of heart with coronary blood vessels, ventral aorta, afferent arteries, efferent loops and hypobranchial arteries.



Text-fig. 24 : *Rhinobatos halavi*, dorsal view of heart with coronary blood vessels.



In *N. concolor*, the last posterior efferent collector joins the anterior, of the same holobranch, at the base and both form a loop (Text-fig. 15), the efferent loops of both sides empty through four pairs of epibranchial arteries which drain into the median dorsal aorta.



Text-fig. 25 : *Rhinobatos halavi*, efferent branchial arteries together with dorsal aorta and some of its branches.

#### D—The Dorsal Aorta and its Main Branches :

In elasmobranchs, the epibranchial arteries carry the oxygenated blood from the branchial efferents to the dorsal aorta, which lies along the ventral surface of the vertebral column and gives rise to the arteries which supply the different regions of the body. It extends along the body to continue into the tail as the caudal aorta.

In *G. cuvier* (Text-fig. 12), the four epibranchial arteries join the dorsal aorta at its lateral sides singly and at nearly equal distances. On each side and at the base of the third epibranchial artery, arises the subclavian artery, which passes obliquely postero-laterally towards the pectoral region, then joins the coracoid artery. The latter passes to the ventral body-wall to meet the coracoid of the other side and form together a large main coracoid artery, which passes forwards on the dorsal surface of the pericardial cavity (adhering to the middle dorsal side of the ventral aorta) and unites with the median hypobranchials (Text-fig. 11). A short distance after the subclavian joins the coracoid, two dorso-lateral arteries arise from the subclavian, an anterior which passes antero-laterally to supply the anterior muscles of the body and a posterior which supplies the posterior muscles. A short distance posterior to these two arteries, the brachial leaves the subclavian and enters the foramen of the pectoral girdle to supply the pectoral fin, where it divides into two branches, a median pterygial and a lateral pterygial, and the latter soon divides into two branches. An unpaired coeliaco-mesenteric artery arises from the ventral wall of the dorsal aorta just posterior to the union of the fourth pair of epibranchial arteries to supply the viscera.

The dorsal aorta then continues posteriorly, giving the two iliac branches which supply the pelvic fins, before it enters the tail as a small caudal artery.

*Nebrius concolor* differs from *G. cuvier* in the origin of the subclavians which in the former (Text-fig-15) originate from the aorta a considerable distance posterior to the place of origin of the fourth pair of epibranchial arteries. The coeliaco-mesenteric axis arises from the ventral side of the dorsal aorta, between the origin of the subclavians, and at its own origin gives a branch to supply the gonads.

The subclavian in *T. lymma* (Text-fig. 19) originates from the side of the dorsal aorta just before the origin of the fourth epibranchial artery. The brachial here differs from the two sharks described above as in supplying the pectoral fin, it divides into two branches : a propterygium which passes anteriorly and divides shortly after its origin giving rise to two branches to supply the anterior and middle muscles of the fin, and a metapterygium which supplies the posterior muscles of the fin by means of numerous smaller branches. An oviducal artery passes from the subclavian, shortly after its origin, to supply the oviduct (this was a mature female specimen).

*Aëtobatus narinari* (Text-fig. 22) has a particularly strong and well marked subclavian artery which originates laterally from the dorsal aorta, a considerable distance anterior to the bases of the fourth pair of epibranchial arteries. The brachial divides into its two branches (propterygium and metapterygium), as in

*T. lymma*, though both branches are here well developed, to supply the larger pectorals ; and the metapterygium is very strong and gives rise to two branches, one passing transversely to supply the middle muscles of the fin and the other posteriorly to supply the posterior muscles of the fin.

In contradistinction with the above, in the transitional batoid, *Rhinobatos halavi* (Text-fig. 25), a single trunk carries the supply of the first, second, and third epibranchial arteries, to the dorsal ; and the fourth epibranchial artery alone leads shortly to the aorta, somewhat posterior to the former trunk. The subclavian emanates from the dorsal aorta just at the base of the fourth epibranchial artery. The brachial divides, as in the rays described above into an anterior propterygium and a posterior metapterygium ; but neither the transverse branch given from the propterygium in *T. lymma* nor that given from the metapterygium in *A. narinari* is developed in *R. halavi*.

#### E.—Hypobranchial arteries :

In elasmobranchs, the hypobranchial arteries form the most complex system of vessels in the ventral wall and floor of the pharyngeal region. This system is formed by the small vessels which connect the ventral ends of the efferent branchial loops.

In *G. cuvier* (Text-fig. 10) the first and second loops are connected by a lateral hypobranchial artery, and similarly are the third and fourth loops. A commissural artery passes transversely from the first loop and connects with that of the other side (in the pharyngeal wall, dorsal to the ventral aorta) (Text-fig. 11). Four commissural arteries extend on each side respectively from the second, third and fourth loops, as well as the last efferent collector ; and all join the corresponding hypobranchial artery. On the dorsal wall of the ventral aorta, the commissural arteries continue to connect the two median hypobranchials. Each of the latter extends along the latero-dorsal wall of the ventral aorta (Text-fig. 11) from just anterior to the second afferent rearwards to a distance before the fourth afferent artery, where each median hypobranchial gives from its ventral wall a pericardial artery. This passes posteriorly to supply the dorsal wall of the pericardial cavity, then continues towards the middle side of the dorsal wall of the ventral aorta ; where the two median hypobranchial arteries unite, just opposite to the origin of the fourth pair of afferent arteries, and form a large main coracoid artery. This continues posteriorly on the dorsal wall of the ventral aorta and adheres to the dorsal wall of the conus arteriosus.

*Nebrius concolor* possesses a relatively simple hypobranchial system. A lateral hypobranchial attaches the first and second loops (Text-fig. 14). A short median

hypobranchial extends on each of the lateral sides of the ventral aorta, in the region between the third and fourth afferent arteries. The last posterior efferent collector joins a common artery of the fourth loop, and a commissural artery from each of the second, third and fourth loops joins the corresponding median hypobranchial. Two small commissural arteries pass transversely on the dorsal side of the ventral aorta at the bases of the second and third loops, and connect the two median hypobranchials. The pericardial artery arises from the median hypobranchial at a level between the bases of the third and fourth commissurals (Text-fig. 13). The coracoid artery arises at the right side from the base of the right median hypobranchial artery and passes obliquely adhering to the dorsal wall of the conus arteriosus (Text-fig. 14).

A rather different case is found in *T. lymma* (Text-fig. 17), where lateral hypobranchials are missing, resembling the case described by Daniel (1934) in *Dasyatis dipterura*. The first loop is not connected to the second one ; and the two median hypobranchials extend from a distance somewhat anterior to the second afferent artery and pass latero-ventrally towards the middle of the ventral side of the ventral aorta, and unite ventrally nearly between the fourth pair of afferent arteries ; as well as dorsally (at the same level) where a main coracoid artery passes dorso-laterally close to the conus. A commissural artery from each of the second, third and fourth loops joins the median hypobranchial of its side. The last efferent collector joins the median hypobranchial directly. The pericardial artery arises at the base of each median hypobranchial just before its union dorsally with its fellow.

*Aëtobatus narinari* (Text-fig. 20) has two long median hypobranchials passing on the lateral sides of the ventral aorta, along the distance between the first and second loops ; and continue latero-ventrally along the ventral aorta ; and are then joined dorsally posterior to the fourth pair of afferent arteries to give the main coracoid artery (Text-fig. 21). Commissural arteries from the bases of all the four loops as well as from the last efferent collector join the median hypobranchials. The latter are connected transversely by two commissural arteries on the dorsal side of the ventral aorta (at the bases of the first and second loops) as well as by a third ventral one, passing at the bases of the third loops. The pericardials originate asymmetrically ; the left arising from the base of the left median hypobranchial, just anterior to the conus arteriosus ; while the right is given at the same level, but from the coronary artery (which branches from the left median hypobranchial). A main coracoid artery originates from the base of the last dorsal commissural artery (Pl. V, Fig. 3 and Text-fig. 21).



The two median hypobranchials in *R. halavi* pass lateral to the ventral aorta, from opposite the second loop rearwards till the second afferent trunk, where they turn to pass ventral to it. As usual, commissural arteries are present and pass from the first ; second and third loops only. A commissural artery from the last efferent collector as well as from the fourth loop joins that of the third loop. The two median hypobranchials are connected dorsally by three transverse commissural arteries (Text-figs. 23 and 24).

#### F.—Coronary vessels :

The coronary arteries arise from the hypobranchial arteries. The coronary veins pour directly into the sinus venosus.

In *G. cuvier*, two well developed coronary arteries arise, one on either side, from the base of the last commissural (Text-fig. 10) and then bend upwards toward the ventral side of the ventral aorta ; both arteries are short and pass obliquely towards the middle where they unite (nearly between the fourth pair of afferent arteries) to form a strong middle artery. This continues posteriorly along the middle side of the ventral aorta, reaching the origin of the conus arteriosus where it gives rise to two well-developed coronary arteries : a lateral right and a ventral median. The lateral right coronary artery extends latero-dorsally (Text-figs. 10 and 11) and supplies the ventro-lateral, as well as the latero-dorsal wall of the conus ; and then divides at the base of the latter, on the right to give rise to two branches which pass to the ventricle as a well-developed dorsal median branch, which supplies the dorsal surface of the ventricle ; and a lateral right branch which supplies the right wall of the ventricle, ventrally and dorsally. The ventral median coronary artery (Text-fig. 10) extends along the conus arteriosus and passes shortly to the ventricle, where it divides into three branches, a median and two laterals ; all of which supply the ventral wall of the ventricle, and in addition the median branch gives numerous others which turn over the apex to supply the posterior dorsal wall of the ventricle. Dorsally, at the beginning of the conus, another coronary branch arises from the main coracoid artery ; and after a short distance divides into two, one to supply the dorsal wall of the conus, and the other passes to the auricle.

In *G. cuvier* blood is collected from the wall of the conus arteriosus by numerous vessels which pour into a right coronary vein (Text-fig. 10) that extends ventrally along the right side of the conus arteriosus and parallel to the right coronary artery. After receiving several vessels collecting from the ventral part of the right wall of the ventricle, the right coronary vein turns—at the end of the conus—to the dorsal wall and passes parallel to the base of the conus, then extends to the sinus venosus where it opens near the right side of the right sinu-auricular valve, by a large opening (which reaches  $\frac{1}{2}$  cm. in a specimen 321 cm. long).

A large left coronary vein, passing parallel to the base of the auricle (Text-figs. 10 and 11), receives branches collecting from the ventral part of the left wall of the ventricle, a branch from the auricle and several branches from the dorsal part of the left wall of the ventricle ; then turns dorsally to open into the left side of the base of the left sinu-auricular valve by an opening similar to that of the right coronary vein.

Many collecting branches carry the blood from the dorsal walls of the ventricle and pour into a median coronary vein that opens just posterior to the opening of the right vein. Other cardinal veins (small branches), as described by Daniel (1934) in some elasmobranchs, are not present here.

Ventrally, in *N. concolor* (Text-fig. 13) a well-developed left coronary artery arises from the left median hypobranchial at the base of the third loop and passes along the ventral left side of the conus till the base, where it gives rise to the several branches which supply the ventricle. Another two smaller coronary arteries pass from the ventral base of the right median hypobranchial (between the third and fourth loops) and extend posteriorly to supply the ventral wall of the conus and join the left coronary artery at its base.

The dorsal wall of the conus (Text-fig. 14) and the antero-dorsal wall of the ventricle are supplied by certain branches from two coronary arteries arising from the base of the left median hypobranchial. From the coracoid artery, a dorsal coronary artery is given at the base of the conus to supply the dorsal, latero-dorsal and postero-ventral wall of the ventricle. Similarly, a branch arises from the coracoid to supply the auricle.

A large coronary vein which passes at the ventral base of the conus parallel to the coronary artery, receives certain venioles collecting from the ventral walls of the conus and ventricle, turns to the dorsal side where it receives other collecting vessels from the dorsal side of the conus, and then passes posteriorly to open at the base of the right sinu-auricular valve.

On the dorsal side of the ventricle (Text-fig. 14) a collecting vein passes parallel to the lateral coronary branch and collects from the right latero-dorsal wall, then joins other branches collecting from the posterior ventral wall, to form a median coronary vein which opens in the sinus venosus at the left side of the base of the sinu-auricular valve. Collecting veins from the left latero-ventral walls together with one from the auricle join a left latero-ventral vein which turns dorsally to receive collecting branches from the posterior left corner of the ventricle and together form a left dorsal coronary vein. This opens together with the median coronary vein by a common opening (4 mm. in diameter in a specimen 224 cm. long). Numerous small veins (cardinal veins of Daniel. 1934) that collect the blood from the median dorsal walls of the ventricle have numerous openings directly to the posterior margins of the sinus.

*T. lymma* has a single main coronary artery which arises from the base of union of the two median hypobranchials on the ventral side (Text-fig. 17). This artery passes along the median ventral side of the conus arteriosus—or may be slightly to the left—and continues posteriorly giving branches to the left wall of the ventricle, as well as a branch to the auricle. Dorsally (Text-fig. 18), a coronary branch is given from the coracoid at the right side of the base, to supply the dorsal and the ventral right walls of the ventricle.

Blood is collected from the ventral walls of the conus by several venioles which pour into one vein (Text-fig. 17) that turns dorsally to unite with another draining the left wall of the dorsal, as well as with a branch collecting from the auricle. The so-formed main coronary vein opens at the base of the sinu-auricular valve by a middle small opening (Text-fig. 18). Another coronary vein passes parallel to the right side of the coracoid and receives certain venioles, then extends parallel to the base of the conus receiving branches collecting from the anterior dorsal wall of the ventricle, and finally passes to open at the right side of the base of the sinu-auricular valve. Blood collected from the posterior ventral wall of the ventricle, as well as from the dorsal left wall, is drained into a left coronary dorsal vein which opens by a left opening to the sinu-auricular valve.

The conus arteriosus in *A. narinari* has a large left coronary artery (Text-fig. 20) which arises from the base of the left median hypobranchial and extends laterally reaching the ventricle giving rise to branches which supply the wall of the ventricle and auricle. This artery differs slightly in position from one specimen to another, as it lies completely ventral in some cases while ventro-lateral in others. Another coronary branch, extending (ventrally) from the left base of the transverse ventral commissural, supplies the ventral wall of the conus.

Dorsally, a small median branch arises from the last transverse commissural artery, and supplies the dorsal wall of the conus, and a left coronary branch is given from the coracoid artery at the base of the conus.

Small branches collecting from the ventral and dorsal wall of the conus, the auricle and the antero-ventral wall of the ventricle drain into a main coronary vein which opens on the right side at the base of the sinus. A left coronary vein collects blood from the posterior and left ventral walls of the ventricle as well as from the dorsal wall. Few dorsal branches pour into the middle coronary vein.

The arrangement of the coronary arteries and veins of *R. halavi* (Text-figs. 23 and 24) resembles much that in *A. narinari*; though in *R. halavi*, the cardinal veins are numerous and dispersed on the dorsal side of the ventricle.

### Urinogenital System

The mesonephroi lie dorsally on each side of the spinal column. In the sharks, where the body is elongate, the mesonephroi extend as two bands, narrow anteriorly near the base of the liver and somewhat wider posteriorly near the cloacal region. In rays, where the trunk is short, the mesonephroi are short and thickened posteriorly.

#### Female Urinary System :

In *Galeocerdo cuvier* (Text-fig. 26), the kidneys appear as the general case above-described in sharks. As a whole, the kidney consists of multitudes of small lobules, which give evidence to its segmentation.

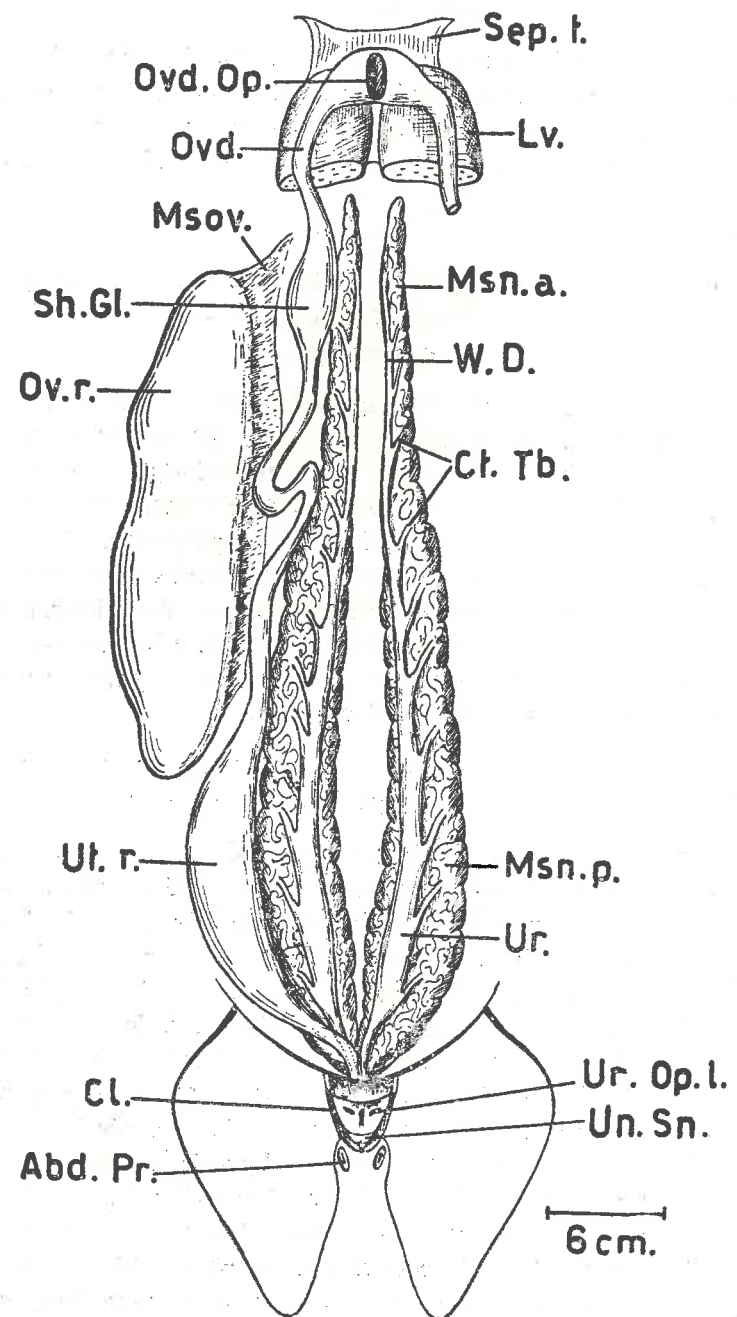
The excretion of each kidney (as is the general case in elasmobranchs) is collected by fine collecting tubules. In the anterior half of the mesonephros, these tubules (about 6) join a fine Wolffian duct, that passes posteriorly on the ventro-lateral surface of the mesonephros to join the corresponding ureter. This extends along the posterior half of the ventral surface of the mesonephros as a thin-walled tube, which gradually increases in width rearwards, and along its course it receives the collecting tubules (6-8) from the posterior mesonephros. Posteriorly, both ureters pass close to one another towards the cloaca, where they become narrower, and open into the dorsal wall of a sac-like structure, the urinary-sinus; this in turn opens by a urinary opening at the tip of a papilla.

In the nurse-shark *Nebrius concolor* (Text-fig. 28), the structure of the urinary system is similar to that of *G. cuvier*, though the mesonephroi are here less lobulated.

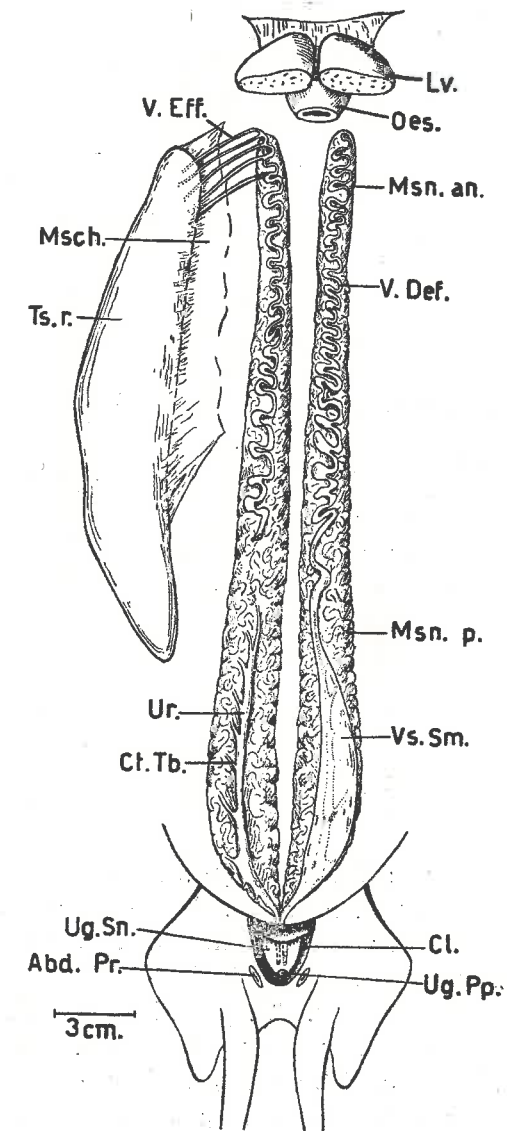
In the ray *Tæniura lymma* (Text-fig. 31), the kidneys are shorter than those described above. The anterior mesonephros is a narrow thin irregular, ribbon-like lobe, with faint transverse partitions. It begins anteriorly a considerable distance posterior to the oviduct on both sides of, and very close to, the vertebral column; and extends posteriorly for a length slightly less than half the total length of the kidney. The posterior mesonephros is a thick lobe which broadens posteriorly, and is formed of a great number of nearly hexagonal lobules. The Wolffian duct is here very fine, extending on the ventro-lateral side of the anterior mesonephros facing the vertebral column, and receives about 8 collecting tubules. Posteriorly, the Wolffian duct joins the ureter which is markedly wide, and increases gradually in width posteriorly. This extends on the latero-ventral surface of the posterior mesonephros very close to the vertebral column. The ureter receives singly the collecting tubules (about 11) of the posterior mesonephros. The two ureters pass close to one another and unite at their entrance to the urinary sinus, where they open by a single opening.

The urinary system of the ray *Aëtobatus narinari* resembles that of *Tæniura lymma* in all respects.

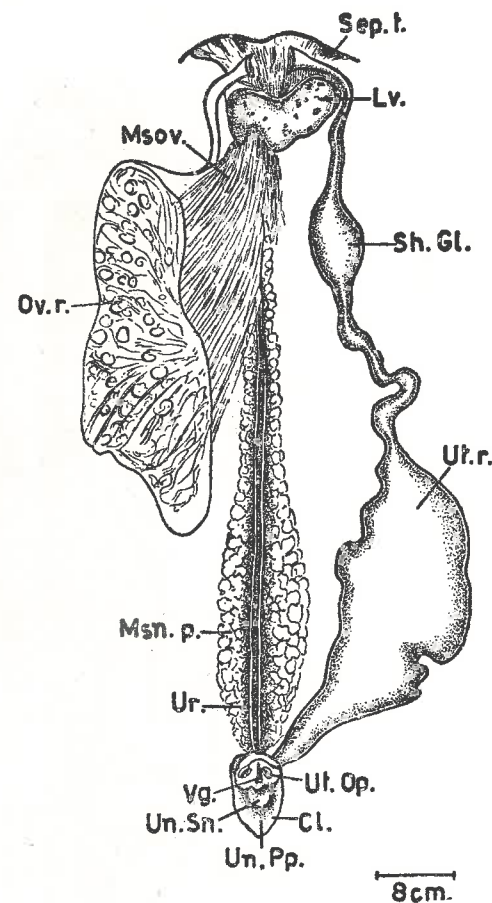




Text-fig. 26 : *Galeocerdo cuvier*, urinogenital system of an adult female (left ovary and oviduct from shell-gland to posterior end are removed).

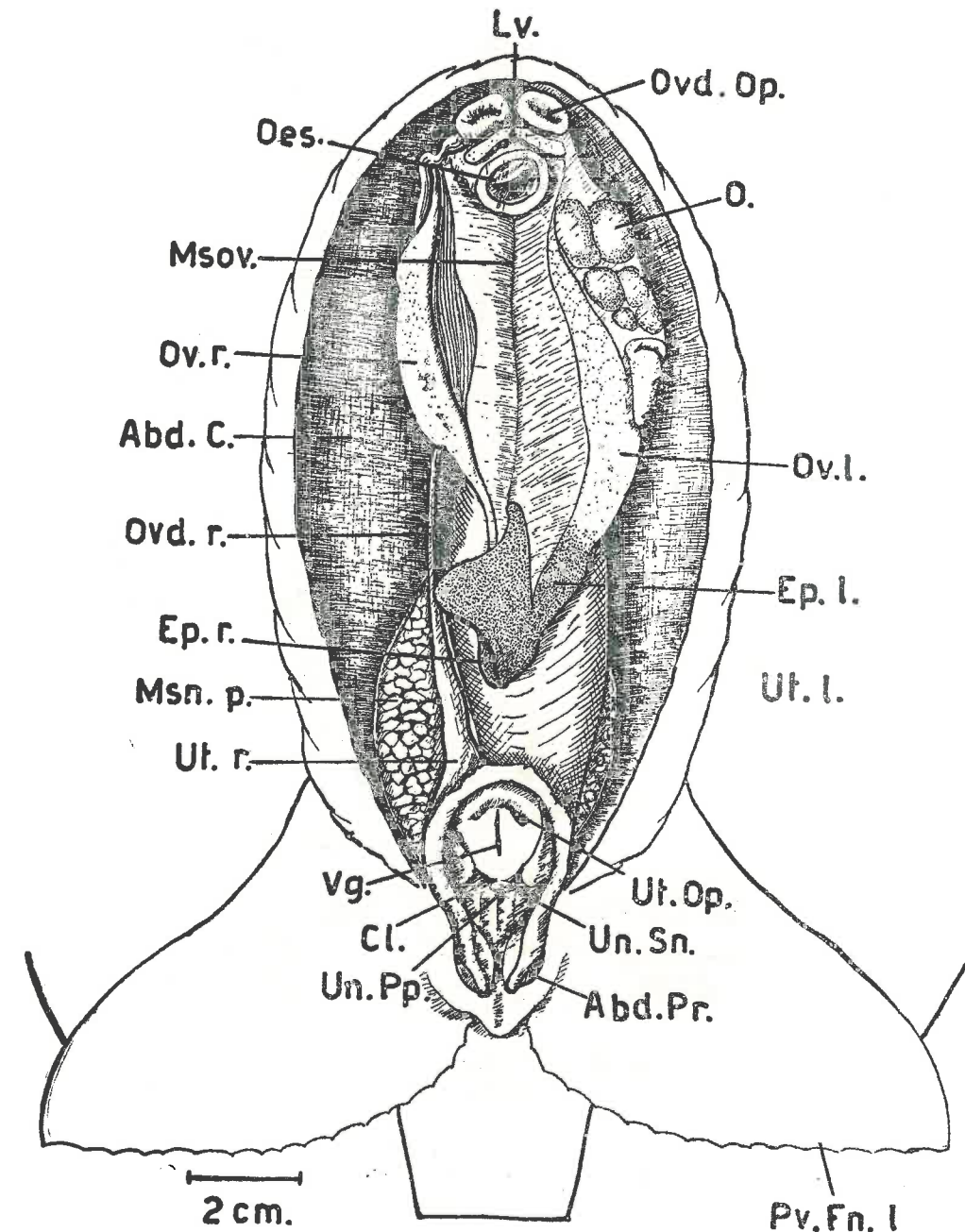


Text-fig. 27 : *Galeocerdo cuvier*, urinogenital system of an adult male.



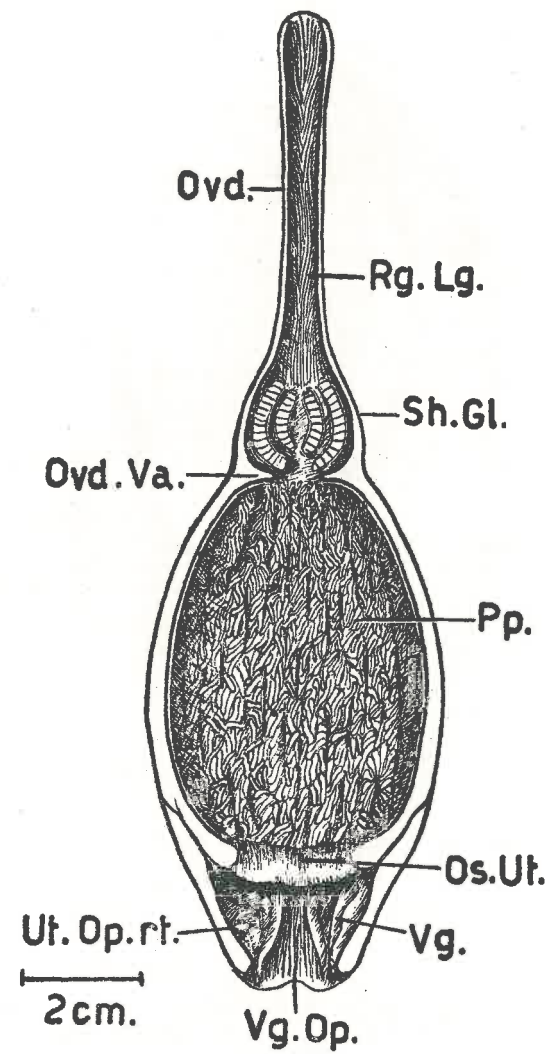
Text-fig. 28 : *Nebrius concolor*, urino-genital system of an adult mature female (left ovary and right oviduct from shell-gland to posterior end are removed).

*Rhinobatos halavi* (Text-fig. 36) and *Rhynchobatus djiddensis* have the same type of urinary system. In these the mesonephroi are characterized by their posterior extension to a distance somewhat posterior to the cloaca. The anterior mesonephros is narrow, as usual, amounts to about one half of the total length of the kidney and is divided into relatively long lobes. The posterior mesonephros is thick, widens gradually posteriorly till opposite the urinary vesicle and then narrows down again. It is markedly divided into large lobes which are in turn divided into numerous rounded lobules. The Wolffian duct passes along the middle of the ventral side of the anterior mesonephros, receiving the collecting tubules (10-11), then joins the ureter which passes medially along the ventral surface of the mesonephros. The ureter continues along the rear portion of the mesonephros which lies on the sides and posterior to the cloaca; and several collecting tubules (about 13) open singly into the ureter along its whole length. A little anterior to the level of the urinary sinus a slender side-tube originates from the ureter passing medially and somewhat posteriorly to join the sinus near the orifice of the tube of the other side.

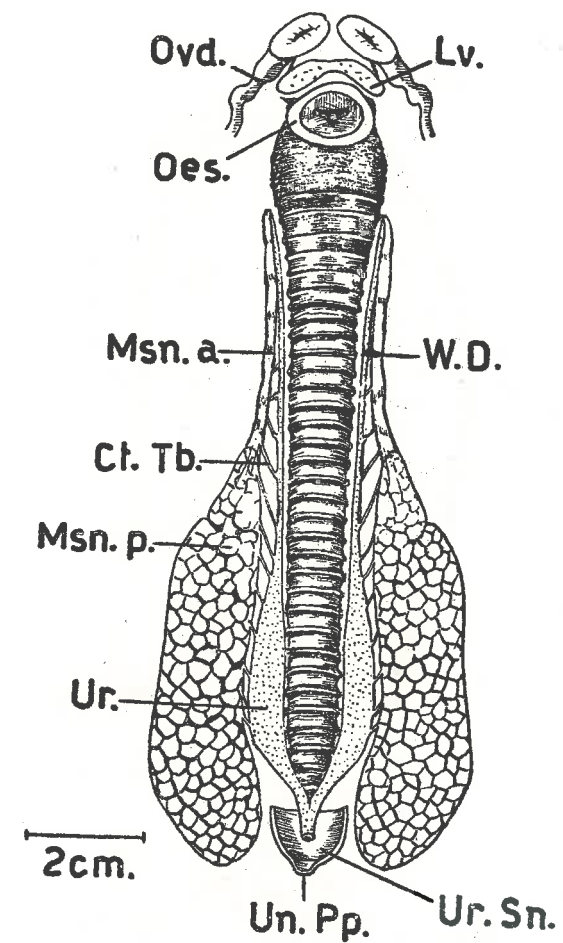


Text-fig. 29 : *Taeniura lymma*, ventral view of the urinogenital system of an adult pregnant female (*in situ*).

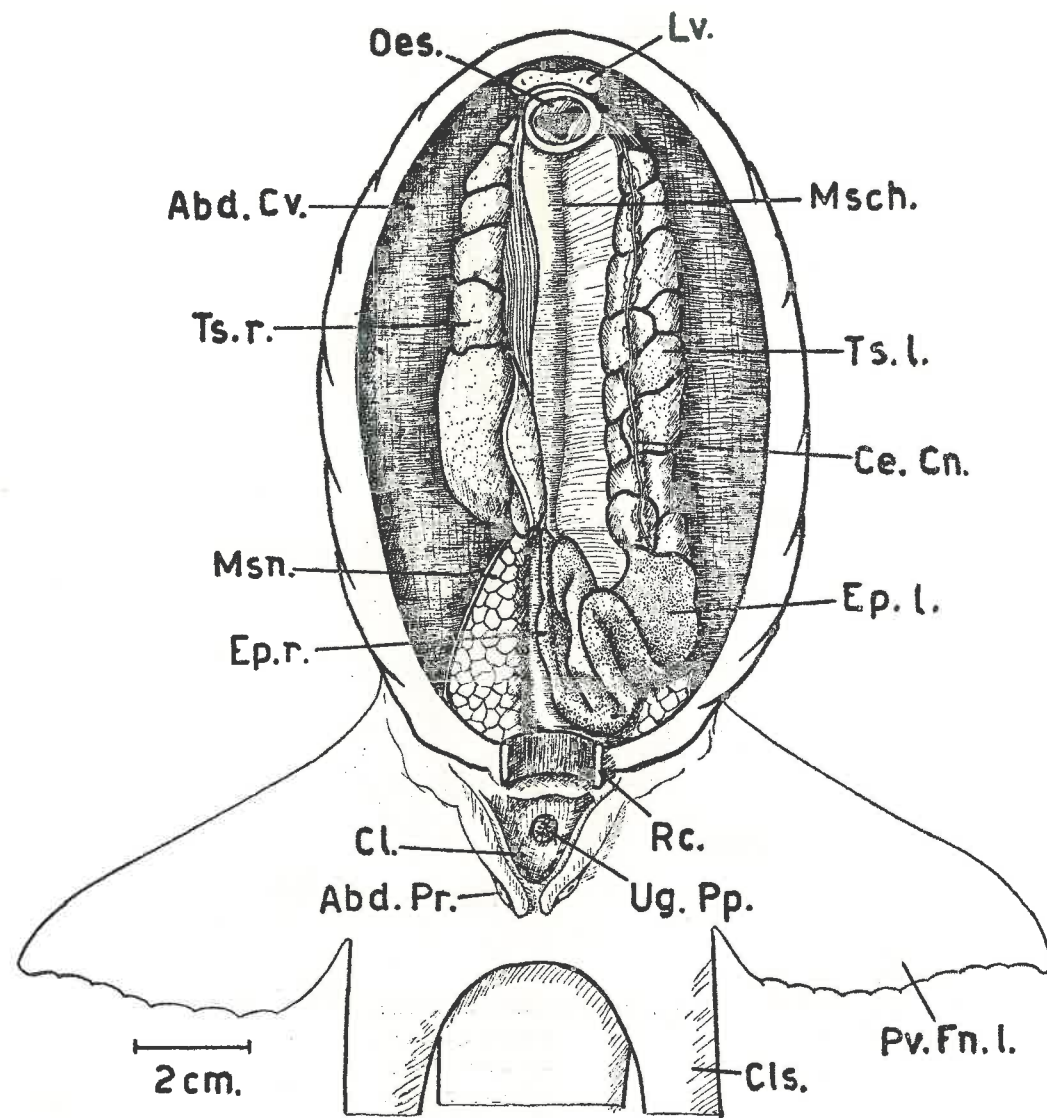




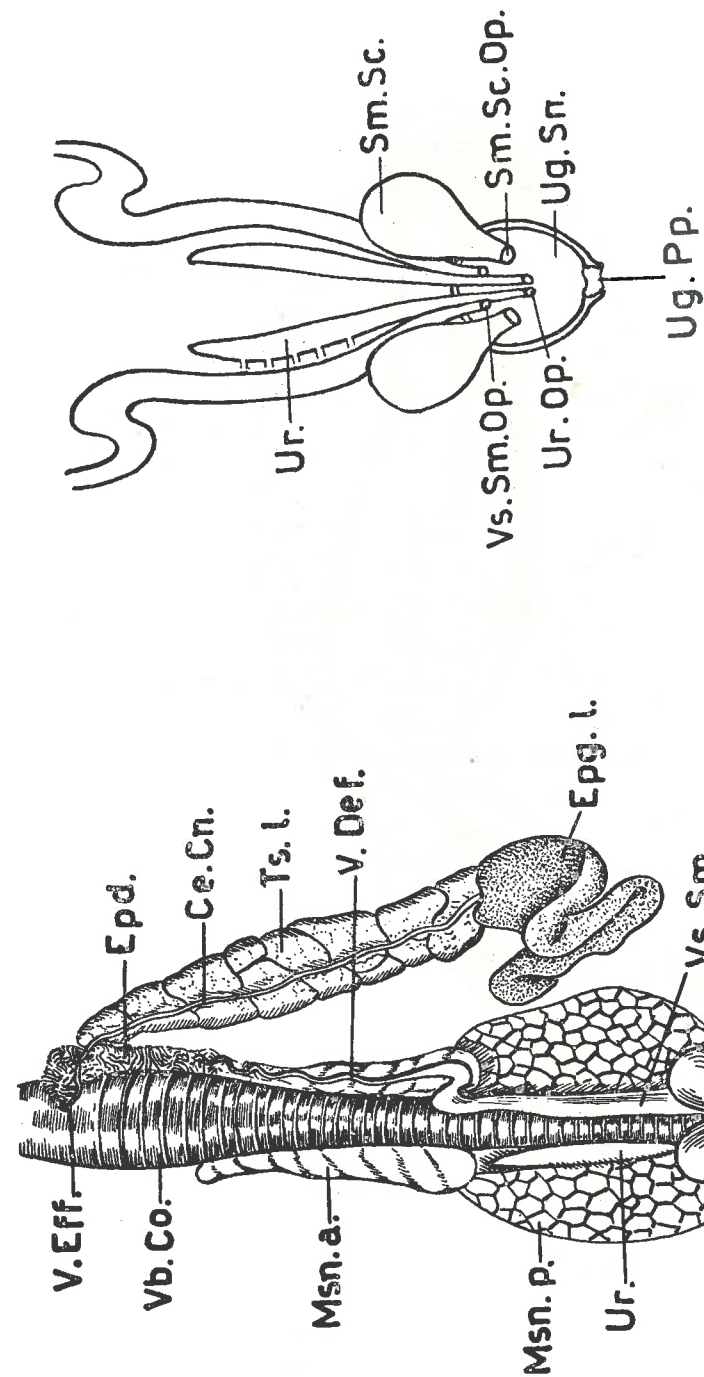
Text-fig. 30 : *Taeniura lymma*,  
right oviduct, uterus  
and vagina opened  
lengthwise ventrally  
to show internal  
structures.



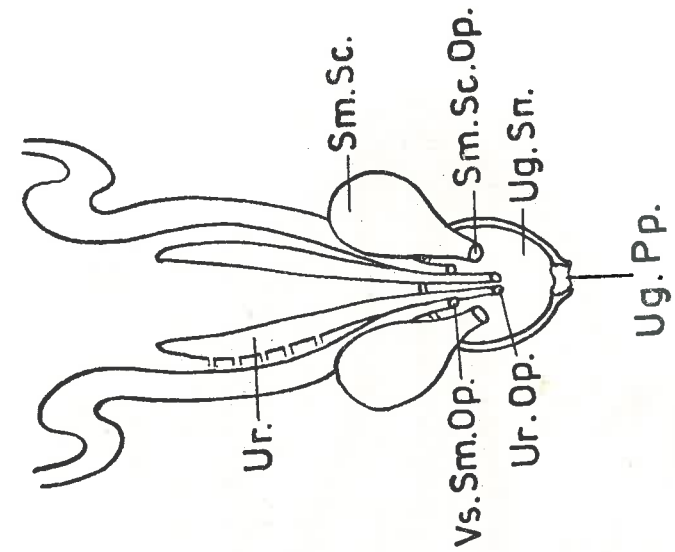
Text-fig. 31 : *Taeniura lymma*,  
urinary system of  
an adult female  
(kidneys are some-  
what stretched  
outwards).



Text-fig. 32 : *Taeniura lymma*, ventral view of urinogenital system of an adult male (*in situ*).

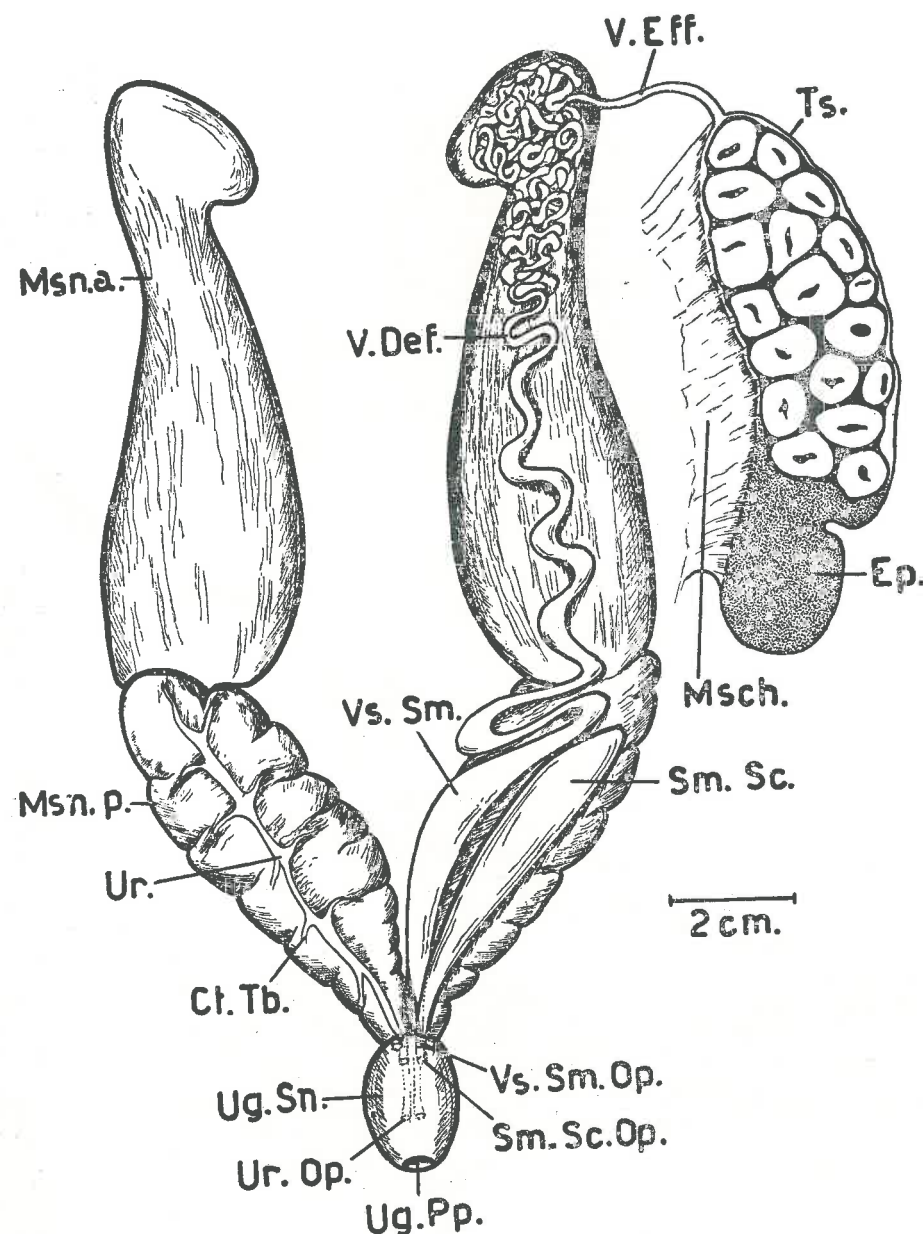


Text-fig. 33 : *Taeniura lymma*, ventral view of urino-genital system of adult male, left testis stretched aside and its mesorchium is cut, the structures of the right side are removed and only the posterior mesonephros, ureter and sperm-sac are present.



Text-fig. 34 : *Taeniura lymma*, diagrammatic representation of the urinogenital sinus opened ventrally to show the openings of the ureters, vesicular seminales and sperm-sacs.





Text-fig. 35 : *Rhinobatos halavi*, urinogenital system of an adult mature male ; the right testis, vas deferens and sperm sac are removed.

### Male Urinary System :

In *Galeocerdo cuvier* (Text-fig. 27) as well as in *Nebrius concolor* the mesonephroi, especially their anterior portions, forming the so-called Leydig's gland, are better developed in males than in females, and the kidneys begin anteriorly and pass rearwards gaining gradually in breadth and thickness. They have the same irregular lobulation as those of the female. The ventral surface of each mesonephros is thrown into a convoluted tube (vas deferens to be described below with the genital system), that represents the Wolffian duct of the female. The ureter is here confined to the posterior mesonephros (about one third of the total length of the kidney) and receives from it 10-11 collecting tubules. The two ureters then pass near one another towards the cloaca, to open on the dorsal wall of the urinogenital sinus.

In the rays *Teniura lymma* and *Aëtobatas narinari*, the anterior mesonephros is much broader in the male than that in the female and attains a greater length. It appears as a separate irregular lobe which abuts on the ventral surface of the anteriormost portion of the posterior mesonephros. This is, in turn, shorter and broader than that of the female and is divided into many lobules. The vas deferens is here much convoluted and complex ; and the ureter is shorter than that of the female and lies on the ventro-lateral side of the posterior mesonephros (facing the vertebral column). Each ureter receives nine collecting tubules and passes to open in the urinogenital sinus (Text-fig. 33).

The male *Rhinobatos halavi* (Text-fig. 35) has the anterior mesonephros, as usual, better developed than the female, and still better than any other species here described. It is a club-shaped unsegmented lobe, with an apex protruding towards the vertebral column, and is relatively longer than the posterior mesonephros. This is also well developed, and is divided into several, relatively large, lobules. Ten collecting tubules open into the ureter which passes along the middle of the ventral side of the posterior mesonephros. The two ureters pass to the dorsal side of the urino-genital sinus to open separately side by side.

The urinary system of *Rhynchobatus djiddensis* conforms with that of *R. halavi*, but the mesonephroi are here larger.

**Female Genital System :**

In mature females of *Galeocерdo cuvier* (Text-fig. 26) two large flattened ovaries lie in the anterior part of the body cavity suspended by the mesovarium. In the non-ovulating season, each ovary contains numerous minute ova embedded in the tissues and not visible externally.

Two oviducts extend along the entire length of the abdominal cavity. Anteriorly, they are located just ventral to the base of the liver; and are attached to the peritoneal-pericardial septum by means of a thin layer of mesentery. Both ducts open into the body cavity through a common median longitudinal slit, the oviducal funnel. Each oviduct passes outwards from the funnel and then inwards toward the anterior part of the kidney, where it enlarges to form the shell-gland. It then, continues rearwards (ventral to the Wolffian duct) till it reaches the mesonephros, where it swells into a long uterus. Each uterus passes posteriorly towards the cloaca, to open separately into the vagina. This, in turn, opens into the cloaca, ventral to and separately from the urinary sinus.

The internal walls of the uteri were found highly vascular and thick.

The female genital system of *Nebrius concolor* (Text-fig. 28) resembles greatly that of *Galeocерdo cuvier* except that each oviduct opens separately into the body cavity.

In the specimen examined, the right ovary was larger than the left and markedly thick and carried numerous ova bulging from its surface.

Internally (Pl. VII, Fig. 1), the lining of the oviduct anterior to the shell-gland is thrown into longitudinal folds. The shell-gland is of relatively immense size and provided with highly muscular walls and a smooth lining. At the end of the shell-gland there is a well developed oviducal valve leading to the posterior oviduct, which is lined with papillated longitudinal folds. This part leads to a distended bag-like uterus (in which were found four thick brownish horny shells, empty in March) and open along one half. The lining of this uterus is thrown into numerous low transverse folds, crossed longitudinally by a great number of very thin villi forming a reticular structure (Pl. VIII, Fig. 2).

In adult female *Tæniura lymma* (Text-fig. 29) two ovaries are found, of which the left is larger and carries numerous small eggs 1-3 cm. in diameter, which are visible through the thin walls of the ovary. In contrast to the sharks described above, the ovary of *Tæniura* has a posterior irregular continuation of a heavy mass of tissue, devoid of ova. This is the rudiment of the epigonal organ, found in some elasmobranchs; and is described to consist of a mass of lympho-myeloid tissue, the centre of formation of erythrocytes as well as leucocytes (Matthews, 1950). The epigonal body of both ovaries extends posteriorly reaching the rectal gland.

Each oviduct opens separately into the abdominal cavity. The oviducts are relatively short, and the right is greatly reduced and leads posteriorly to a small non-functional uterus. On the other hand, the left oviduct is developed, and the shell-gland is large and leads by an oviducal valve to the uterus (Text-fig. 30). This is much distended, and in contrast to the sharks, follows directly the shell-gland.

In a pregnant female with two fully developed embryos, in June, the internal lining of the left uterus was provided with numerous high papillae and at the end of this uterus there was a constricted muscular area representing the os uteri which opened into the vagina.

The genital system of *Aëtobatus narinari* resembles in all respects—even in internal structure of the uterus of the pregnant female—that of *T. lymma*.

Mature *Rhinobatos halavi* resembles *Rhynchobatus djiddensis* in the structure of the genital system. They have well developed ovaries, which were full of large eggs, 3-10 cm. in diameter, from April to October, in the pregnant individuals. In both species the two oviducts are functional, and open into the body cavity by a common oviducal opening. Between May and November, four to five fully developed embryos with external yolk-sacs were found in each uterus of *R. halavi*. In *Rhynchobatus*, in June, a female was obtained which had, in each uterus, four thin-walled egg-cases full of yolk, while another female delivered four young in October, and had the internal lining of the uteri thrown into irregular folds. These are higher and more numerous in *Rhinobatos* (Pl. VII, Fig. 4) than in *Rhynchobatus* (Pl. VII, Fig. 5).

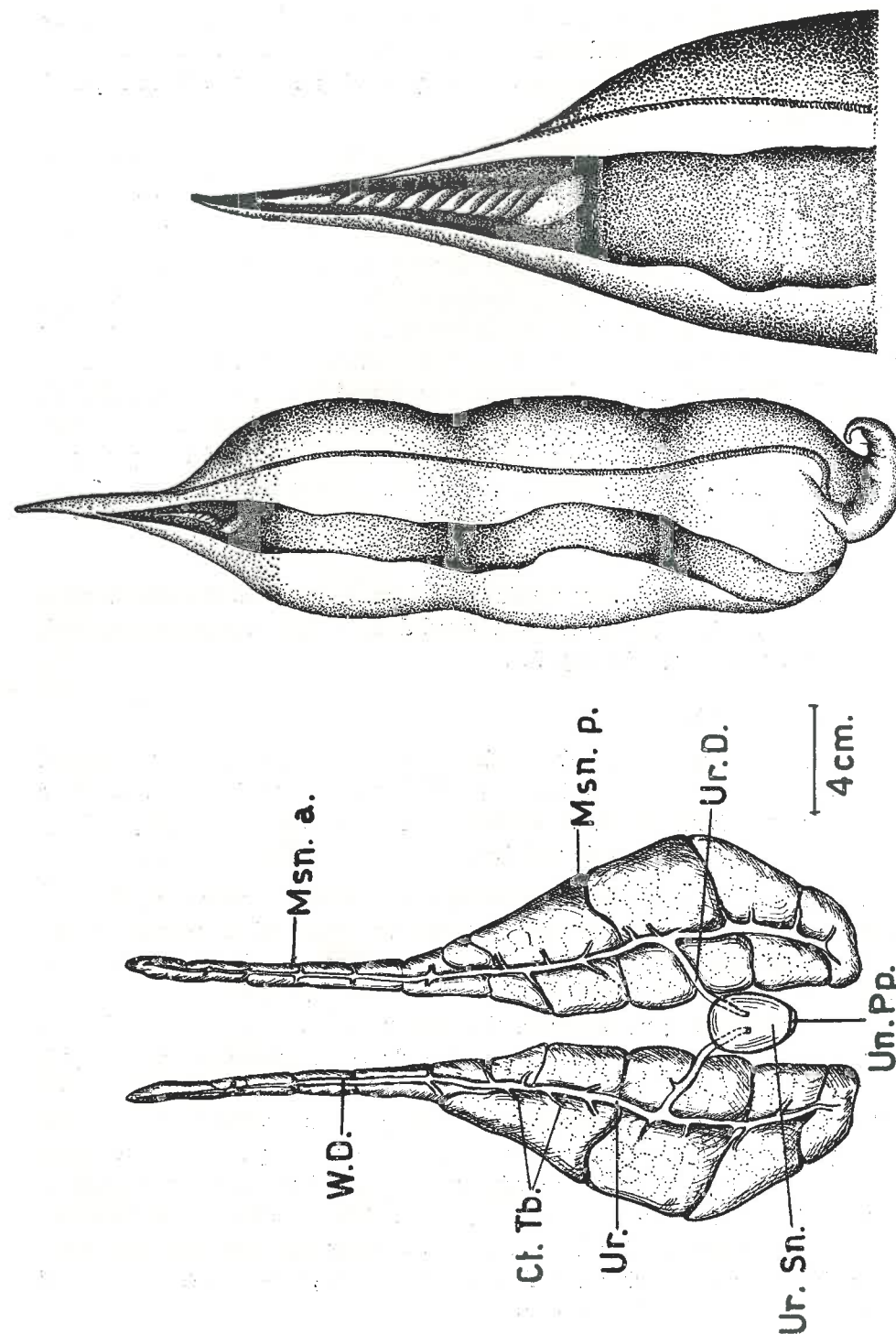
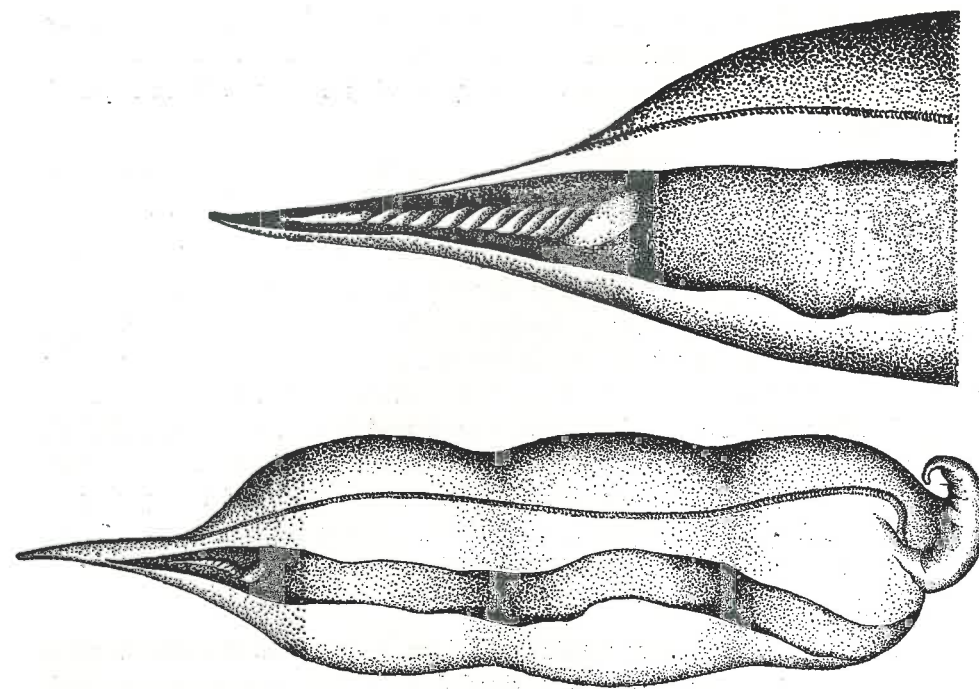
In *Pristis pectinatus* six eggs weighing 4.5 kgm. were extracted from the uteri of one female. The egg-capsule was divided into three compartments, each containing a single egg (Text-fig. 37).

#### Male Genital System :

The genital organs of the adult male *Galeocерdo cuvier* are elongate flattened cream organs, the testes (Text-fig. 27) lying on both sides of the kidneys and extending posteriorly over about two thirds of the length of the abdominal cavity. They are attached to the dorsal body wall by means of a stout mesorchium.

On the ventral surface of the anterior mesonephros (Leydig's gland which changes its function in adult males to the secretion of a kind of spermatic fluid), lies a mass of convoluted tubules, the vas deferens (corresponding to the Wolffian duct of the female) known wholly as the epididymis. Each testis communicates with the corresponding vas deferens, through four minute vasa efferentia, which come out from the anterior end of the testis and pass into the mesorchium to join the vas deferens. Along the anterior two thirds of the ventral surface of the mesonephros, the vas deferens is much convoluted and partly embedded in the superficial mesonephric tissue. Along the posterior third of the mesonephros, the vas deferens becomes less convoluted, and then gradually enlarges to form the vesicula seminalis (ampulla ductus deferentis of Matthews, 1950). The ampullae of the two sides pass posteriorly approaching one another, becoming narrower and then open separately on the antero-dorsal surface of the urino-genital sinus, ventral and lateral to the entrance of the ureters.



Text-fig. 36 : *Rhinobatos halavi*, urinary system of adult femaleText-fig. 37 : *Pristis pectinatus*, Left : Three eggs inside an egg-case. Right : Enlarged part of same.

In a mature male *Nebrius concolor*, the testes are much stouter than those of *Galeocерdo* of equal size. They are ripe and divided into lobules. The vesiculae seminales are developed. A very characteristic organ is the urinogenital sinus which is here conical, long and thick-walled. The urinogenital opening lies at the end of a relatively long posterior portion of the sinus which protrudes freely out of the cloaca.

In an adult male *Tæniura lymma* (Text-fig. 32), the testes are constituted of two long narrow lobes of which the left is longer. Each testis is divided transversely into lobules which are larger in the left testis. Posteriorly, each testis is combined with its corresponding irregular epigonal organ, which reaches posteriorly to the end of the abdominal cavity, where both epigonal bodies attach together and to the rectal gland. The epigonal bodies are not found in either of the two sharks described above. The central canal of the testis is clear, and extends in the middle nearer to the ventral surface. At the anteriormost portion of the testis a single vas efferens comes out from the central canal and joins the vas deferens (Text-fig. 33) which is markedly convoluted and complex and represents the anterior half of the anterior mesonephros, then it becomes deeply embedded posteriorly in the tissues of the mesonephros, and appears again to run straight along the posterior portion of the anterior mesonephros; then it bends rightwards to give the vesicula seminalis, which is here a thick-walled, straight tube, extending along the latero-ventral side of the posterior mesonephros, facing the vertebral column and covering the ureter below it.

Anterior to the urinogenital sinus, and ventral to the end of the vesicula seminalis, lies a blind sub-rounded sac, the sperm-sac. At first sight, it appears as if it were connected to the vesicula seminalis; but when carefully examined, it was found separate. Each sperm-sac is embedded at its end in the antero-dorsal wall of the urino-genital sinus, near and outer to the openings of the vesiculae seminales. Thus, in the urinogenital sinus of the male *T. lymma* open the ureters, the vesiculae seminales and the sperm-sacs (Text-fig. 34).

The male genital organs of *Aëtobatus narinari* are similar in structure to those of *T. lymma*.

The genital system of male *Rhynchobatus djiddensis* resembles that of *Rhinobatos halavi* (Text-fig. 35). It consists of kidney-shaped testes, divided up into a number of irregular lobes provided centrally with fine trabeculae. There is an epigonal organ occupying about the rear third of the testis, and as usual attaches to the rectal gland.

As in *T. lymma*, a single vas efferens emerges from the central canal of the testis and joins the vas deferens. The sperm-sacs are here well-developed elongated blind structures which, as described in *T. lymma*, open into the urino-genital sinus. Daniel (1934, p. 302) stated that the sperm-sacs are of small size in *Squalus* and *Raja* and are described as urinary bladder in some rays.

#### 4. Nervous System

Although several anatomical works have been carried on the brain of different elasmobranchs, e. g. *Chlamydoselachus* (Garman, 1885); *Heterodontus*, *Heptanchus*, *Scoliodon*, *Raja*, *Myliobatis*, *Scymnus* and *Squalus* (Daniel, 1934); *Cetorhinus* (Matthews and Parker, 1950) and *Manta* (Gohar and Bayoumi, 1959) yet—as far as we are aware—no work was done on the brain of *Galeocerdo cuvier*, *Nebrius concolor*, *Taniura lymma*, *Aetobatus narinari*, *Rhinobatos halavi* or *Rhynchobatus djiddensis*. Therefore, the anatomy of the brain and the cranial nerves of the above-mentioned species is here described.

#### The Brain :

For the study of the brain, the head was injected with 40% formaldehyde solution and after allowing it sufficient time to harden, the brain was exposed and studied *in situ*. It was then extracted from the neurocranium.

When examined *in situ* the brain is found to differ in size, relative to the brain-case, from one species to another.

In the adult shark *N. concolor* (Pl. VII, Fig. 4) as well as in *G. cuvier*, the brain is relatively small and occupies about the posterior half of the brain-case, to the shape of which it is moulded. Accordingly, the brain is elongated, and somewhat compressed laterally. In a specimen of *N. concolor*, 215 cm. long and 50 kgm. in body weight, the brain weighed 27 gm.; while in one of *G. cuvier*, 305 cm. long and 150 kgm. in body weight, the brain was only 50 gm.

The rays *T. lymma* (Pl. IX, Fig. 5) and *A. narinari* (Pl. IX, Fig. 4) have large brains, compared with the above-described sharks. The brain occupies more than two thirds of the cranium, and its general shape especially in *A. narinari*, is broader than that of the previously described sharks. The weight of the brain of an adult specimen of *T. lymma*, 67 cm. long and 1.330 kgm. in body weight, was 18 gm., and in an adult *A. narinari*, 218 cm. long and 70 kgm. in body weight it was 90 gm.

The transitional batoids, *R. halavi*, *R. djiddensis* and *R. ancylostoma*, have comparatively smaller brains than those of the above described rays; and the brain resembles that of sharks in occupying the posterior, somewhat less than half, part of the brain-case. The weight of the brain was 11 gm. in an adult individual of *Rhinobatos halavi* (171 Cm. long and 15 Kgm. in body weight) and the brain of an adult *Rhynchobatus djiddensis* (280 Cm. long and 110 Kgm. body weight) weighed 40 gm.

As usual in all vertebrates, the brain in these species is made up of five divisions, the telencephalon, the diencephalon, the mesencephalon, the metencephalon and the myelencephalon.

#### The Telencephalon :

This is the largest part of the brain, and differs in shape from one species to another. It is somewhat roundish in *G. cuvier* (Pl. VIII, Fig. 1) and *N. concolor* (Pl. IX, Fig. 1); but tends to be long and angled in *T. lymma* (Text-fig. 38) and *A. narinari* (Pl. X, Fig. 1), but in *R. halavi* (Pl. X, Fig. 4) and *R. djiddensis* (Pl. XI, Fig. 4) it is short and broad.

Dorsally, the telencephalon appears as a compact mass; and the bilobed nature found in some elasmobranchs e. g. *Heterodontus francisci* (Daniel, 1934, p. 231), is slightly indicated by a superficial longitudinal sulcus, at the middle of the anterior portion of the brain better seen in *N. concolor* (Pl. VIII, Fig. 4) and *T. lymma* (Pl. IX, Fig. 5). The dorsal surface of the telencephalon is elevated to form the so-called pallial eminences.

The median olfactory nucleus projects slightly as an anterior rounded ventrally directed projection. It is somewhat more developed in *G. cuvier*, *N. concolor* and *T. lymma* (Pl. VIII, Fig. 4, Pl. IX, Fig. 2 and Text-fig. 38). The median nucleus is separated dorsally from the pallial eminences by a transverse sulcus, the pallial sulcus, which is best seen in *Taniura lymma* and *Nebrius concolor* (Pl. IX, Fig. 1).

Ventrally, the telencephalon is divided by a median superficial septum, into two massive corpora striata (Pl. VIII, Fig. 3, Pl. IX, Fig. 2, Text-fig. 39., Pl., Fig. 2 and Pl. XI, Fig. 1).

Two olfactory lobes bulge laterally, on either side of the telencephalon, and are attached dorsally to the median olfactory nucleus and ventrally to the corpus striatum. The olfactory lobes join the olfactory bulbs posterior to the corresponding olfactory organ by means of the olfactory tracts. These differ in the extent of their development and extension, according to the position of the brain in the brain-case as well as the situation of the nostrils and the degree of their separation.



In *N. concolor* and *G. cuvier*, where the brain occupies a posterior position in the chondrocranium; and the nostrils are relatively widely separated, the olfactory tracts reach their maximum length and pass parallel to one another for a considerable distance after which they diverge each towards its corresponding olfactory organ.

*A. narinari*, where the brain occupies most of the brain-case and the nostrils lie near together (separated by an isthmus) possesses short and thick olfactory tracts, which pass parallel to one another and end in the bulbs which are—in contrast to the above-described sharks—very near to one another.

*Taeniura lymma* possesses shorter and thicker olfactory tracts which are also parallel and have bulbs situated nearer than in *A. narinari*.

The olfactory tracts are widely divergent and particularly short in *Rhinobatos halavi* and *Rhynchobatus djiddensis* (Pl. XI, Figs. 1 & 4). This is in agreement with the position of the nostrils which are comparatively widely situated.

#### The Diencephalon :

The telencephalon continues posteriorly into the diencephalon, the roof of which is hidden by the anterior portion of the cerebellum. However, in *G. cuvier* (Pl. VIII, Fig. 1) there is, near the end portion of the telencephalon, a median cavity roofed by a thin layer, the anterior choroid plexus. This opening leads into the cavity of the diencephalon, the third ventricle. In the middle of the thin roof of the diencephalon and posterior to the anterior choroid plexus, there is a ganglionic part the 'habenular ganglion', from which the pineal stalk had arisen.

The diencephalon continues posteriorly, gradually narrowing to the place of the optic chiasma; from the posterior and ventral surface of which the infundibulum hangs down (Pl. VIII, Fig. 3, Pl. IX, Fig. 2, Text-fig. 39, Pl. X, Fig. 2 and Pl. XI, Fig. 1) and backward; and at its sides, anteriorly, are the rounded inferior lobes (lobi inferiores) and, posteriorly, the vascular sacs (sacci vasculosi) lie. The pituitary organ lies along the middle portion in between the sacs of both sides.

In *G. cuvier* the inferior lobes are rounded and well developed; and are partly ventrally covered by the underlying pituitary body. The sacci vasculosi, on the other hand, are much developed and pass to the dorsal side of the middle part of the pituitary. These sacs are thin-walled and highly vascular. The pituitary body is well-developed and extends anteriorly reaching the optic lobes; and thus the infundibulum is hidden in *G. cuvier* by the well developed inferior lobes, the vascular sacs and the pituitary organ. The pituitary body is here externally divided into four well defined divisions: a roundish anterior part, an elongated middle part (largest part), and two lateral posterior portions, which are the smallest and are partly hidden by the vascular sacs.

The inferior lobes in *N. concolor* are relatively less developed than in the case of *G. cuvier*, and the vascular sacs are much reduced. The pituitary organ is simpler and much smaller than that of *G. cuvier*, as it is here formed of a continuous mass, faintly divided externally into an anterior elongated lobe, a middle nearly rounded part and a posterior very small rounded third lobe, and the superficial longitudinal sulcus passing along the middle line of practically the whole pituitary organ is deeper and better detected than in *G. cuvier*.

In *Taeniura lymma* the vascular sacs—in contrast with the above-described species—have thick walls. The pituitary body of *T. lymma* has, besides the four lobes found in that of *Nebrius concolor*, a pair of superior lobes which lie in between the sides of, and dorsal to, the intermediate and posterior lobes.

*A. narinari* has well developed inferior lobes and vascular sacs, and the pituitary forms a longitudinal continuous broad lobe which narrows only at the middle portion.

In *R. halavi* as well as in *R. djiddensis* the vascular sacs are small. The pituitary is also small, and is formed of two parts, a long thin stalk which passes between the inferior lobes and continues into a triangular small lobe, that lies between the anterior half of the vascular sacs. This is followed by the apex of the triangular second portion; which is highly vascular and extends posteriorly to a considerable distance behind the vascular sacs.

#### The Mesencephalon :

The mesencephalon varies considerably in the different species. In some forms it is relatively inconspicuous, being hidden dorsally, under the well-developed cerebellum and ventrally by the infundibulum and associated structures, while in others it is well-developed and clear.

The roof of the mesencephalon is composed of a right and a left optic lobes, which vary in the degree of development in the different species.

In *G. cuvier*, the optic lobes are of enormous size, form two rounded structures lying close to each other and are highly elevated. Although they are partly covered by the cerebellum, yet they can be seen dorsally (Pl. VIII, Fig. 1) and better than in lateral view (Pl. VIII, Fig. 2).

The optic lobes are very small and completely hidden by the cerebellum in *Nebrius concolor* and *Aëtobatus narinari*, though in the former they are visible laterally (Pl. IX, Fig. 3 and Pl. X, Fig. 3). They are moderately developed in *Taeniura lymma* (Text-figs. 38 and 40) and *Rhynchobatus djiddensis* (Pl. XI, Fig. 4) where they are visible both dorsally and laterally.

The third cranial nerve (the oculomotor) passes through the ventral walls of the mesencephalon, from which the fourth nerve (the trochlear) arises dorsally.

### The Metencephalon :

This segment of the brain is usually large in elasmobranchs, and especially dorsally, where it is developed into the large cerebellum.

In *G. cuvier*, the cerebellum (Pl. VIII, Fig. 1) is rhomboid moderately developed and its dorsal surface is divided by two transverse furrows into three divisions, of which the anterior is the smallest and the posterior the largest, these do not extend greatly posteriorly, and accordingly the proximal portion of the medulla oblongata is clear.

The cerebellum in *N. concolor* (Pl. IX, Fig. 1) is relatively longer than that of *G. cuvier*, and has the dorsal surface, more or less, divided transversely into nearly ten divisions, which decrease gradually in size posteriorly. The optic lobes and the restiform bodies, lying ventral to the cerebellum, are completely hidden by the latter.

In the two transitional batoids, *Rhinobatos halavi* (Pl. X, Fig. 4) and *Rhynchobatus djiddensis* (Pl. XI, Fig. 4) the cerebellum has become narrower and longer than the forms described above. It has superficial longitudinal, and deep transverse furrows dividing it into a number of lobes which are more numerous in *R. djiddensis*. Owing to the laterally compressed character of the cerebellum in both forms, the optic lobes as well as the restiform bodies are clear.

The divisions of the elongated cerebellum are increased in *T. lymma* (Text-fig. 38) and the lobules are more separated than in the species described above and tend to be convoluted.

*A. narinari* possesses a complex cerebellum (Pl. X, Fig. 1) of immense size, the surface of which is thrown into numerous irregular folds, and in this respect it is similar to *Manta ehrenbergi* as described by Gohar and Bayoumi (1959).

### The Myelencephalon :

This is the last segment of the brain formed of the medulla oblongata. As in all elasmobranchs, it is a Y-shaped structure, the anterior limbs of the Y being the restiform bodies (corpora restiforme).

In *G. cuvier*, owing to the relatively short cerebellum, the restiform bodies are very clear dorsally (Pl. VIII, Fig. 1) and are ear-like structures which form the lateral boundaries of the fourth ventricle. The latter can be seen dorsally as a triangular space through the thin translucent roof, the 'tela choroidea'. The cranial nerves, posterior to the fourth, arise from the medulla, which posteriorly tapers gradually to the spinal cord.

In *N. concolor*, the restiform bodies are markedly small resembling those of *G. cuvier* in the ear-like structure, but are completely hidden dorsally under the cerebellum and can be seen in lateral view (Pl. IX, Fig. 3).

*R. halavi* and *R. djiddensis* resemble *G. cuvier* in the restiform bodies, being visible dorsally, but these bodies are somewhat convoluted in *R. halavi* (Pl. X, Fig. 4) and more so in *R. djiddensis* (Pl. XI, Fig. 4).

*T. lymma*, has small and convoluted restiform bodies, which are partly visible dorsally (Text-fig. 38) but are clearer in lateral view (Text-fig. 40).

The large convoluted cerebellum of *A. narinari* completely hides the moderately developed restiform bodies lying below. These are, however, clear laterally (Pl. X, Fig. 3).

### The Cranial Nerves :

#### I.—The Olfactory Nerve :

The olfactory nerve (in elasmobranchs) extends from the olfactory bulb as a double nerve forward to the epithelium of the olfactory capsule. The bulb joins the olfactory lobes of the brain by means of olfactory tracts, which differ in the different species, being long, thin and parallel in *N. concolor* (Pl. III, Fig. 4) and *G. cuvier*, but short and thick in *A. narinari* (Pl. IX, Fig. 4) and more so in *T. lymma* (Pl. IX, Fig. 5). *R. halavi* and *R. djiddensis* (Pl. IX, Fig. 4) have the shortest and most widely divergent tracts.

The terminal nerve, characteristic for elasmobranchs, is found in all species, though it is very thin and hardly differentiated. It is best seen in *T. lymma* (Text-fig. 38). It starts from each side of the median olfactory nucleus, and passes dorsally median to the olfactory tract, then divides at the base of the olfactory bulb into two divisions which end in the olfactory capsule.

#### II.—The Optic Nerve :

This is a well-developed nerve which originates from the diencephalon ; then the two nerves cross to form the optic chiasma (Pl. VIII, Fig. 3, Pl. IX, Fig. 2, Pl. X, Fig. 2 and Pl. XI, Fig. 1). Each nerve passes longitudinally and upward, penetrates the lateral side of the chondrocranium through a large optic foramen, to reach the retina of the eye.

The optic nerve is markedly well developed in *G. cuvier* and *A. narinari*, moderately developed in *T. lymma*, *R. halavi* and *R. djiddensis* and relatively slightly developed in *N. concolor*.



### III.—The Oculomotor Nerve :

This nerve originates from the floor of the mesencephalon (Pl. VIII, Fig. 3, Pl. IX, Fig. 2, Text-fig. 39, Pl. X, Fig. 2 and Pl. XI, Fig. 1) and passes under the associated structures of the infundibulum toward the lateral side of the chondrocranium, penetrating it through the oculomotor foramen (situated posterior to and somewhat upward of the optic foramen) and passing to the muscles of the eye where it gives four branches ; three of which to the internal, superior and anterior rectus muscles (respectively) and the fourth to the inferior oblique muscle of the eye.

This nerve is best developed in *Galeocerdo cuvier* (Pl. VIII, Fig. 3) while it is particularly poorly developed in *Nebrius concolor* (Pl. IX, Fig. 2).

### IV.—The Trochlear Nerve :

This arises from the roof of the mesencephalon, at the most posterior end of the optic lobe, as a relatively thin nerve. The origin and posterior portion of the nerve are hidden by the cerebellum dorsally, but are seen in lateral views (Pl. VIII, Figs. 1 and 2, Pl. IX, Fig. 1, Text-figs. 38 and 40, Pl. X, Fig. 4 and Pl. XI, Fig. 2). This nerve passes upwards lateral to the optic lobes crossing the oculomotor nerve and penetrates the chondrocranium, through a small trochlearis foramen, above the optic foramen, and emerges to supply the superior oblique muscles of the eye.

### V.—The Trigeminal Nerve :

This nerve is thick and arises from the ventral surface of the anteriormost portion of the medulla oblongata just below the anterior tip of the restiform body (Pl. VIII, Fig. 3, Pl. IX, Fig. 2, Text-fig. 39, Pl. X, Fig. 2 and Pl. XI, Fig. 1). In all the dissected species, except *R. halavi* and *R. djiddensis*, the trigeminal is directed a short distance antero-laterally, and together with the buccalis branch of the facial, passes through the trigeminal foramen. The trigeminal nerve then divides into its three branches (the ophthalmicus, maxillaris and mandibularis). On the other hand, the trigeminal in *R. halavi* and *R. djiddensis* passes together with the buccalis and the ophthalmicus branches of the facial, and the abducens nerve, all directed laterally, to penetrate the skull through a large foramen prooticum.

### VI.—The Abducens Nerve :

In *G. cuvier* (Pl. VIII, Fig. 3), *N. concolor*, *R. halavi* (Pl. XI, Fig. 1) and *Rhynchobatus djiddensis*, the abducens nerve arises from the ventral side of the medulla oblongata, somewhat posterior to the facial VII, and towards the median line, while in *T. lymma* (Text-fig. 40) and *A. narinari* (Pl. X, Fig. 2) the abducens arises from the latero-ventral side of the medulla oblongata, at a point just posterior to the trigeminal.

In all cases —except *R. halavi* and *R. djiddensis*— the abducens nerve passes outwardly and somewhat anteriorly ; and leaves the brain through its own abducens foramen, somewhat posterior to the trigeminal foramen, and proceeds to supply the external rectus muscle of the eye.

*R. halavi* and *R. djiddensis*, as mentioned before, have the abducens nerve passing together with the trigeminal, and buccalis and ophthalmicus branches of the facial through the large foramen prooticum.

### VII.—The Facial Nerve :

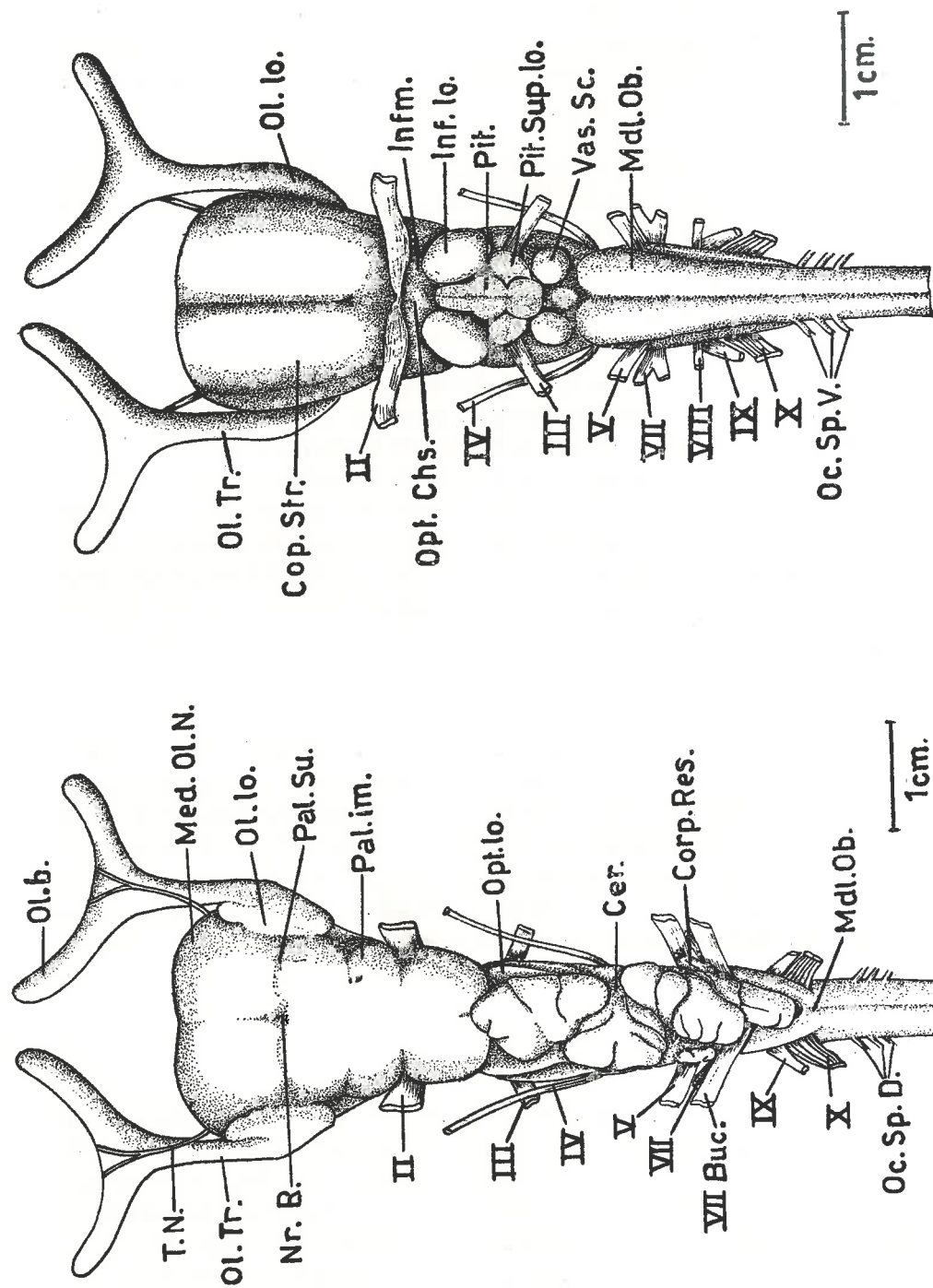
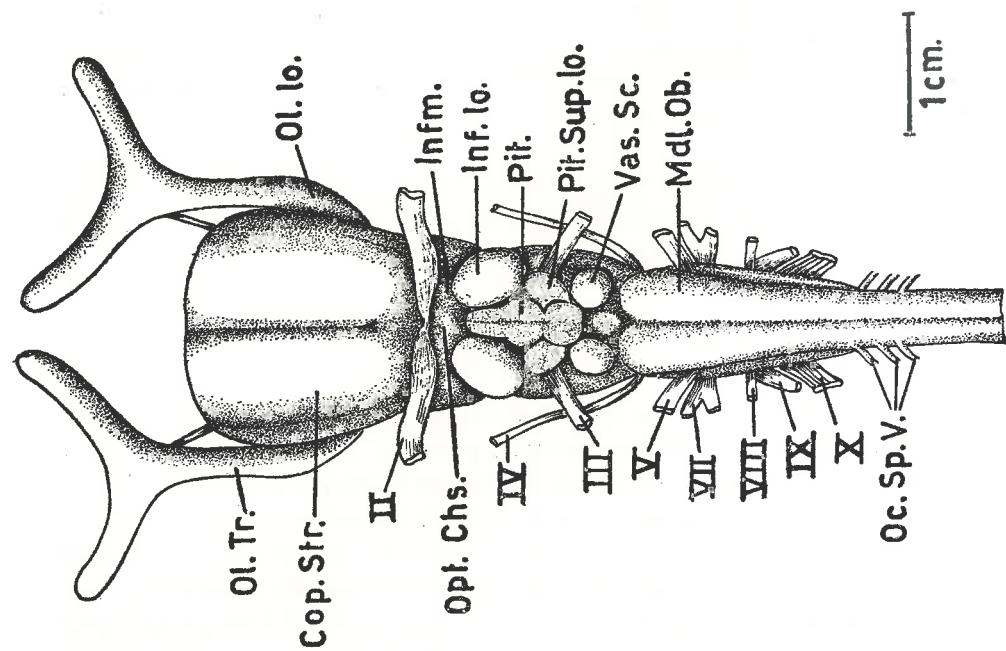
This nerve arises, in all the species described here, in two roots. The first root originates from the medulla oblongata posterior and inner to the corpora restiforme (Pl. VIII, Fig. 2, Pl. IX, Fig. 3, Text-fig. 40, Pl. X, Fig. 3 and Pl. XI, Fig. 2) and joins the second root which originates from the lateral side of the medulla, at the same level as the trigeminal and slightly posterior to it. As described before, the buccalis branch of the facial joins the trigeminal, while the other root passes outwards for a short distance to come out through the facial foramen and gives rise to its branches, the ophthalmicus, the hyomandibularis and the palatine.

### VIII.—The Auditory Nerve :

This nerve always arises separately and, in all the described forms, it comes out from the ventro-lateral side of the medulla oblongata. It originates nearly below the last segment of the cerebellum as seen in *N. concolor* (Pl. VIII, Fig. 4 and Pl. IX, Fig. 3), *T. lymma* (Text-figs. 39 and 40), *A. narinari* (Pl. X, Figs. 1 and 2), *R. halavi* (Pl. XI, Figs. 1 and 2) and *R. djiddensis* (Pl. XI, Fig. 4). Only in *G. cuvier* (Pl. VIII, Figs. 2 and 3) does this nerve arise somewhat rearwards and dorsal to the abducens. The auditory passes laterally penetrating its own foramen to supply the auditory capsule of its side.

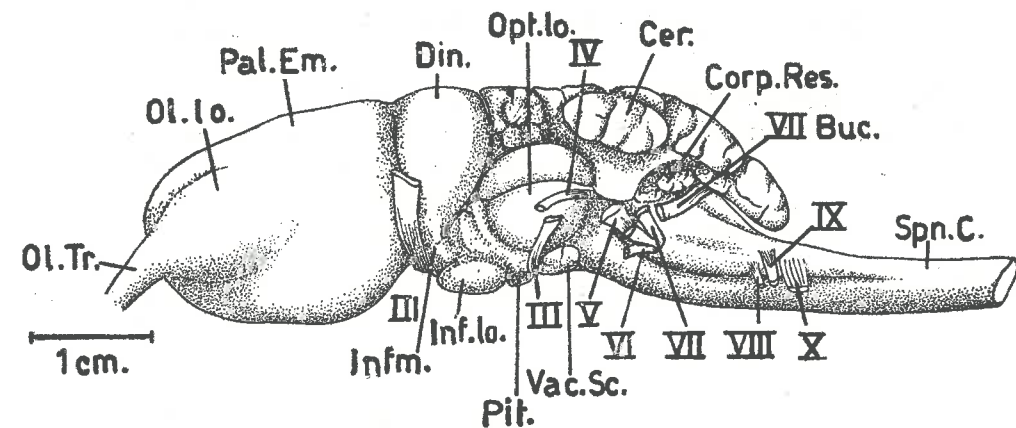
### IX.—The Glossopharyngeal Nerve :

This comes out from the lateral side of the medulla oblongata, somewhat dorsal and posterior to the auditory nerve very close to the origin of the vagus nerve (Pl. VIII, Fig. 3, Pl. IX, Fig. 3, Text-fig. 40, Pl. X, Fig. 2, and Pl. XI, Fig. 1). It is then directed, a little outwards posteriorly side by side with the vagus and then penetrates the lateral wall of the neurocranium separately through the glossopharyngeal foramen and then passes through a glossopharyngeal canal traversing the auditory capsule, supplying the first gill.

Text-fig. 38 : *Taeniura lymma*, dorsal view of brain and cranial nerves (of a specimen 67 cm. long).Text-fig. 39 : *Taeniura lymma*, ventral view of brain and cranial nerves.

## X.—The Vagus Nerve :

This nerve arises from the lateral wall of the medulla oblongata, just posterior to the Glossopharyngeal origin, as a thick nerve with five maxillaries arising side by side and extending a little outward and posteriorly beside the glossopharyngeal (Pl. VIII, Fig. 3, Pl. IX, Fig. 3, Text-fig. 40, Pl. X, Fig. 2, and Pl. XI, Fig. 1) to penetrate the lateral wall of the neurocranium, through a large vagus foramen. The first four branches of the vagus extend to supply the last four gills, while the fifth branch is a visceral one and supplies the heart, stomach and other viscera.

Text-fig. 40 : *Taeniura lymma*, lateral view of brain and cranial nerves.

## 5. Head Skeleton

The skull as usual is composed of two portions, the neurocranium and viscerocranium. To the neurocranium, the brain-case or cranium proper, are fused the olfactory capsules in front and the auditory capsules behind. Between these capsules on each side, are found the orbits in which the eye-balls are lodged. The optic capsule, which is represented by the sclerotic cartilage, does not fuse with the brain-case but is generally held away from the cranial wall by the cartilaginous optic stalk or pedicel which is fused with that wall.

The viscerocranium, on the other hand, consists of the visceral arches which surround the buccal cavity and pharynx. The number of these arches is seven in the majority of selachians. They may be divided into two groups, one comprising the first and second visceral arches, the mandibular and hyoid arches, which are closely associated with the neurocranium forming the jaw apparatus and suspensorium, the other consisting of the remaining five visceral branchial arches which support the walls of the pharynx.



Typically the visceral arch in Selachii is  $\Sigma$ -shaped consisting of four cartilaginous bars. In the branchial arches the two intermediate bars, the epibranchial dorsally and ceratobranchial ventrally, are well developed. Each of these segments, except those of the last arch, bears a single row of cartilaginous branchial rays radiating outwards in the gill septa. Attached to the epibranchial and ceratobranchial are the pharyngobranchial and the less developed and backwardly pointing hypobranchial, respectively. The hypobranchials of both sides are joined together in the mid-ventral line by one or more unpaired basibranchials. In the case of the mandibular and hyoid arches, as well as the last branchial arch, the number of the component cartilaginous elements is subjected to reduction as a result of the disappearance or fusion of some of these elements.

The first visceral or mandibular arch, which carries the teeth, bends over the corner of the mouth and is composed of two segments on either side, an upper palatoquadrate or pterygoquadrate and a lower mandibular segment or Meckel's cartilage. The palatoquadrates of both sides which form the upper jaw are attached together anteriorly and free posteriorly. Similarly are the two Meckel's cartilages which form the lower jaw. The palatoquadrate is generally regarded as the epimandibular element and Meckel's cartilage as the ceratomandibular (Furbringer, 1903).

Following the mandibular arch are the spiracular cartilages, which support the wall of the reduced spiracular pouch. These spiracular cartilages vary in number and shape in different selachians, and views differ concerning their morphological significance. Some authors (Huxley, 1876 and Edgeworth, 1925) considered the spiracular cartilage as a separate otic process, others (Gegenbaur 1872, Holmgren 1936, El-Toubi 1947 and Hamdy 1955 a) considered the spiracular cartilages as modified mandibular rays.

In most Selachii the hyoid arch is composed of a dorsal hyomandibular and a ventral ceratohyal. Connecting the two ceratohyals of both sides in the mid-ventral line is the unpaired basihyal. The hyomandibular articulates with the wall of the auditory capsule by its dorsal end. It is generally considered as the epihyal, which corresponds serially to the epibranchials of the visceral arches lying behind it (Gegenbaur, 1872). In Selachioidei the ceratohyal lies below the hyomandibular, the two elements being directly connected with each other. The cartilaginous rays borne on these segments are the hyal rays. In Batoidei, on the other hand, there is no cartilaginous element below the hyomandibular. But behind this latter cartilage is a two-segmented cartilaginous rod carrying the hyal rays. This rod is considered by Gegenbaur (1872) as representing the ceratohyal which became disconnected from its hyomandibular and extended upwards behind it, and by Krivetski (1927)

as the fused bases of the hyal rays, and he terms it the pseudohyoid, in contradistinction to the ceratohyal of Selachioidei with which it is not homologous. Krivetski bases his conclusion on the fact that the afferent pseudobranchial artery, on running forwards from the efferent hyoidean artery, is median to the pseudohyoid of Batoidei, whereas it is lateral to the ceratohyal of Selachioidei. This view though rejected by Edgeworth (1931) has been accepted by de Beer (1932) and Hamdy (1952 and 1956).

Lying outside the visceral arches are the extravisceral cartilages which form dorsal and ventral regular series. They are differentiated into the labial, extrahyoid and extrabranchial cartilages corresponding to the mandibular, hyoid and branchial arches respectively. The shape and number of these extravisceral cartilages differ in the different selachians. Their nature and origin have been for many years the subject of discussion by many authors. Rathke (1832) homologizes them with the outer branchial arches of cyclostomes, while Jaekel (1895) considers them as secondary structures in the skin. Gegenbaur (1872), Dohrn (1884), Haswell (1884), Foote (1897), El-Toubi (1952), and Hamdy (1955 b) believe that the extrahyal and extrabranchial cartilages are but modified hyal and branchial rays.

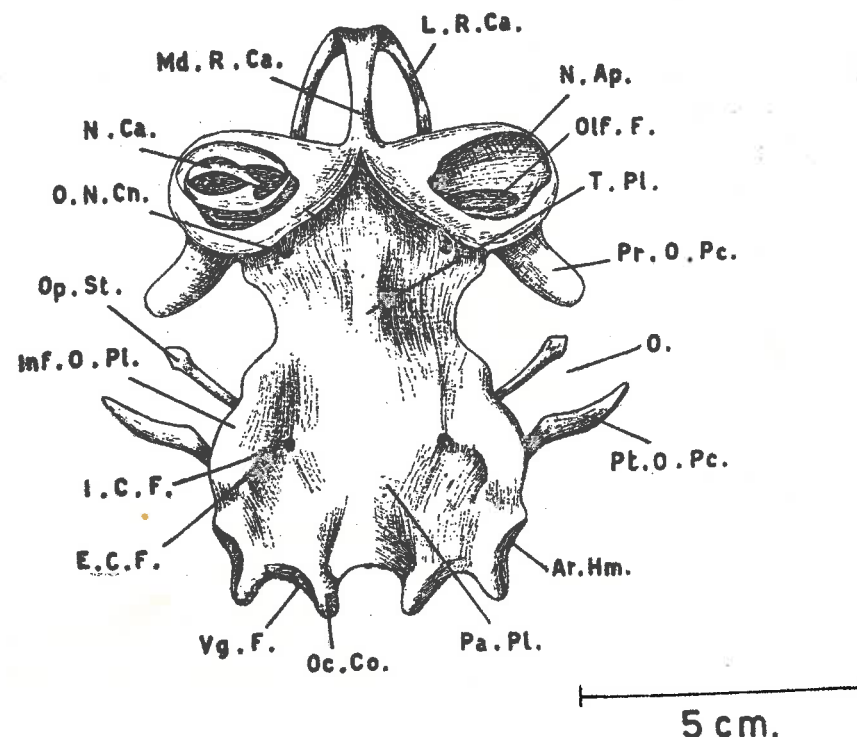
The head skeleton of some species of elasmobranchs from the Red Sea were described by Hamdy (1952, & 59) and Melouk (1957) and thus, a detailed study of the head skeleton of only one species *Aprionodon brevipinna* (Selachoid) is given here.

#### A.—The Neurocranium of *Aprionodon brevipinna* :

As in all Selachii, the roof, sides and floor of the dorso-ventrally compressed brain-case of *Aprionodon brevipinna* are welded into a single piece of cartilage, to which are fused the olfactory capsules (Text-fig. 41, N. Cp.) in front and auditory capsules (Aud. Cp.) behind.

The rostrum is supported by a median rostral cartilage (Md. R. Ca.) representing the anterior prolongation of the trabecular plate, and two lateral rostral cartilages (L. R. Ca.) extending forwards from the roof of the nasal capsules and converging to unite with the median element anteriorly to form a dorso-ventrally flattened cartilaginous part which is markedly concave dorsally and convex ventrally. This triradiate rostral skeleton is considered typical of the Galeoidei (White, 1937).

Anteriorly, the cranial roof connecting the orbital cartilages is remarkably convex, and anterior to this roof lies a nearly triangular and relatively large supracranial fontanelle (S. Cr. Fn.), which leads to the cranial cavity but extends anteriorly over the cavum praecerebrale (Cv.Pr.Cb.) enclosed between the three rostral cartilages. Usually in Selachioidei, the anterior opening lying dorsally in the neurocranium is nomenclated collectively without reference to its nature, whether supracranial, precerebral or a combination of the two. It is called the prefrontal fontanelle by Gegenbaur (1872) and the anterior fontanelle by Goodey (1910). Gegenbaur (1872) considers this fontanelle as a perforation of the cranial roof, and defines it as a median opening in the cranial roof.



Text-fig. 41 : *Aprionodon brevipinna*, Dorsal view of neurocranium.

Parker (1879) considers that in sharks the roof of the cranium ceases close to the nasal sacs and as a result the cranial cavity is open in front, but no fontanelle exists. Allis (1913) looks on the anterior dorsal fontanelle of the selachoid neurocranium as a perforation of the cranial roof. In 1923, he described the anterior fontanelle in *Chlamydoselachus* to consist of two morphologically different parts; a perforation of the anterior wall of the cranial cavity, filled with a jelly-like connective tissue, and which he called fenestrum praecerebralis, and a large open depression immediately anterior to that perforation, which he called cavum praecerebrale. Allis stated for convenience that the fenestrum praecerebralis and cavum praecerebrale could be given the name «anterior cranial opening». In the same publication, Allis stated that the fenestrum praecerebralis in *Acanthias* was occluded by the morphological anterior wall of the cranial cavity and thus considered the anterior fontanelle to be precerebral in position, as it represents the dorsal opening of the cavum praecerebrale.

Thus, the supracranial fontanelle is represented in some Selachioidei but is lacking in others. In the latter case the cavum praecerebrale enclosed between the cartilaginous support of the rostrum lies directly anterior to the cranial roof. Accordingly, it is not correct to include the anterior cavity in the «anterior fontanelle».

as it does not represent a perforation of the cranial roof which leads to the cranial cavity. It also seems improper to nomenclate this cavity without referring to its nature and position in relation to the cranial and precerebral cavities.

As a matter of fact, in *Aprionodon brevipinna* the brain extends anteriorly in front of the posterior edge of the dorsal opening lying anteriorly, i. e. the morphological anterior wall of the cranial cavity begins before the hind end of this opening which, thus, lies partly above the cranial cavity and partly above the precerebral region of the neurocranium. For this reason this opening could be differentiated into two morphologically different parts; an anterior triangular part, the cavum praecerebrale (Cv. Pr. Cb.), and a posterior supracranial part, the supracranial fontanelle (S. Cr. Fn.). The precerebral cavity lies between the rostral cartilages. The supracranial fontanelle, on the other hand, lies close to the nasal capsules and distinctly posterior to the morphological anterior wall of the cranial cavity.

The posterior region of the cranial roof, represents both the tectum synoticum, connecting the auditory capsules and the tectum posterius, connecting the two halves of the occipital arch fused together.

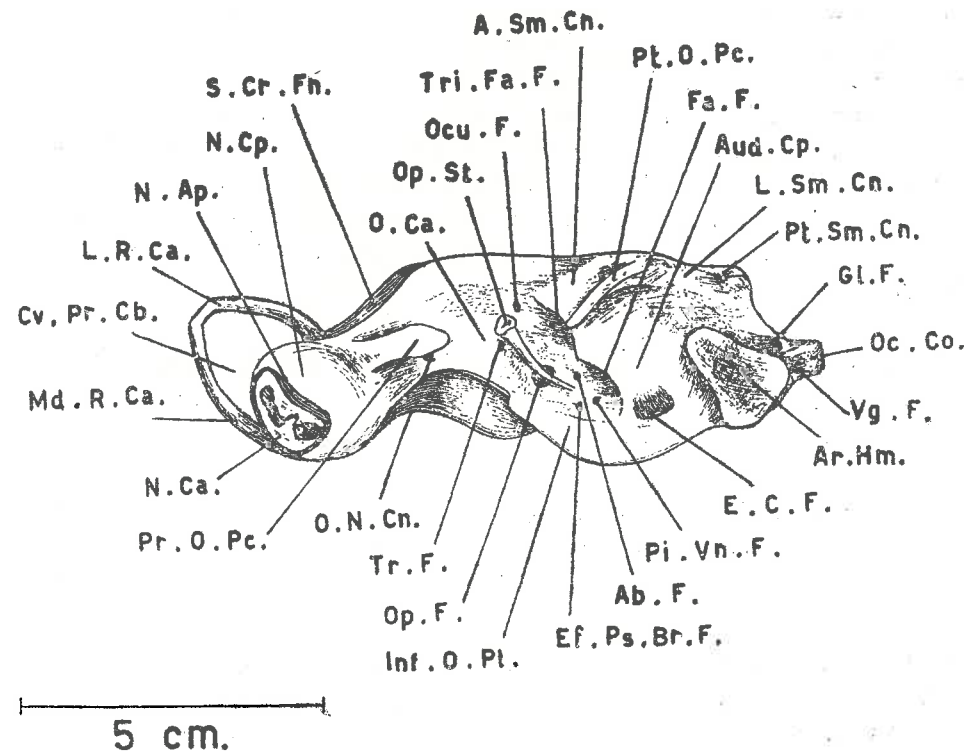
Below the hind end of the lateral rostral cartilage is found the nasal capsule, which is broader than long and relatively thin-walled especially at the ventral edge. It opens ventrally to the exterior by a wide oval nasal aperture.

In the auditory capsules, the semicircular canals and the organs of hearing are located. Between the auditory capsules is a moderate shallow depression, the endolymphatic fossa (End. Fo.), which is nearly triangular and sliding backwards and from it two pairs of foramina lead to the auditory capsules. The two anterior foramina afford passage for the endolymphatic ducts and are known as the endolymphatic foramina (End. F.). They are narrow and circular in shape. The two posterior foramina are relatively much larger and nearly oval in shape, and each leads directly into the perilymphatic cavity of an auditory organ and is known as the perilymphatic foramen (per. F.).

The external prominences indicating the position and size of the semicircular canals (A. Sm. Cn., L. Sm. Cn., Pt. Sm. Cn.) are not quite distinct, and the endolymphatic fossa is shallow. This corroborates Daniel (1928) who notes that in Selachii with deep endolymphatic fossa, the position of the semicircular canals is evident, while in those having shallow endolymphatic fossa the external evidence of these canals is less distinct.



The posterior part of the lateral walls of the neurocranium (Text-fig. 42) is formed by the auditory capsules which are vertically situated on either side. The posterior region of the auditory capsule is provided laterally with the well developed articular surface for the dorsal end of the hyomandibular (Ar. Hm.). This surface is in the form of a deep depression with a nearly triangular rim. Its ventral edge is represented by that of the auditory capsule.



Text-fig. 42 : *Aprionodon brevipinna*. Lateral view of neurocranium.

Anterior to the auditory capsule, the side-wall of the brain-case is formed of the orbital cartilage (O. Ca.).

The supraorbital cartilage, extending lateral to the dorsal edge of the orbital cartilage in most Selachii, is absent in *Aprionodon brevipinna*.

In front of the orbit and at the dorso-lateral edge of the hind wall of the nasal capsule is a well developed preorbital process (Pr. O. Pc.) extending posteriorly, and behind the orbit is a postorbital process (Pt. O. Pc.) extending nearly from the middle of the lateral wall of the auditory capsule and arches forwards. Generally in Selachii, the preorbital and postorbital processes represent, the extension of

the supraorbital cartilage in front of and behind the orbit respectively. Thus, in *Aprionodon brevipinna* only the anteriormost and posteriormost parts of the supraorbital cartilage are represented, forming the pre- and post-orbital processes. The preorbital process has the normal relations and position, but the postorbital process is remarkably shifted posteriorly towards the anterior end of the auditory capsule. This region generally represents the posterior end of the orbit in Selachii. Extending from the orbital cartilage (O. Ca.), nearly at the beginning of its posterior third, is a slightly twisted, rod-shaped structure, the optic pedicel or stalk (Op. St.). It is made up of softer cartilage than the rest of the neurocranium and its base is completely fused with the adjacent orbital wall. This stalk projects antero-laterally and is slender posteriorly and widens out to a terminal expansion which abuts against the eye-ball.

Harrison (1931) considered the optic stalk as an outgrowth from the lateral surface of the chondrocranium while El-Toubi (1949) stated that, in *Acanthias vulgaris* the optic stalk appeared as a separate structure and fused with the orbital wall later on in development. Gegenbaur (1872) states that the base of the optic stalk in Selachii is always composed of somewhat firmer tissue than the rest of the stalk and is considered by him to belong to the chondrocranium rather than to the eye-stalk. In *Aprionodon brevipinna*, there is no external distinction between the proximal and distal ends of the optic stalk to favour the one view or the other.

The optic foramen (Op. F.) occupies a nearly central position in the orbit. Posterior to this is the facial foramen (Fa. F.) which affords passage for the buccal, palatine and hyomandibular branches of the facial nerve. Postero-dorsal to the optic foramen is a wide foramen trigemino-facialis (Tr. Fa. F.), which gives exit to the trigeminal nerve as well as the ophthalmic branch of the facial nerve.

Anterior to the trigemino-facialis foramen, the orbital cartilage is penetrated by a small foramen transmitting the oculomotor nerve (Ocu. F.), and below and slightly anterior to it is the trochlear foramen (Tr. F.). Nearly at the middle of the distance between the facial and optic foramina lies a small foramen transmitting the abducens nerve (Ab. F.). Below the facial foramen is the pituitary vein foramen (Pi. Vn. F.). Anterior to the latter and slightly ventrally is the efferent pseudobranchial foramen (Ef. Ps. Br. F.) which lies in line below the abducens foramen.

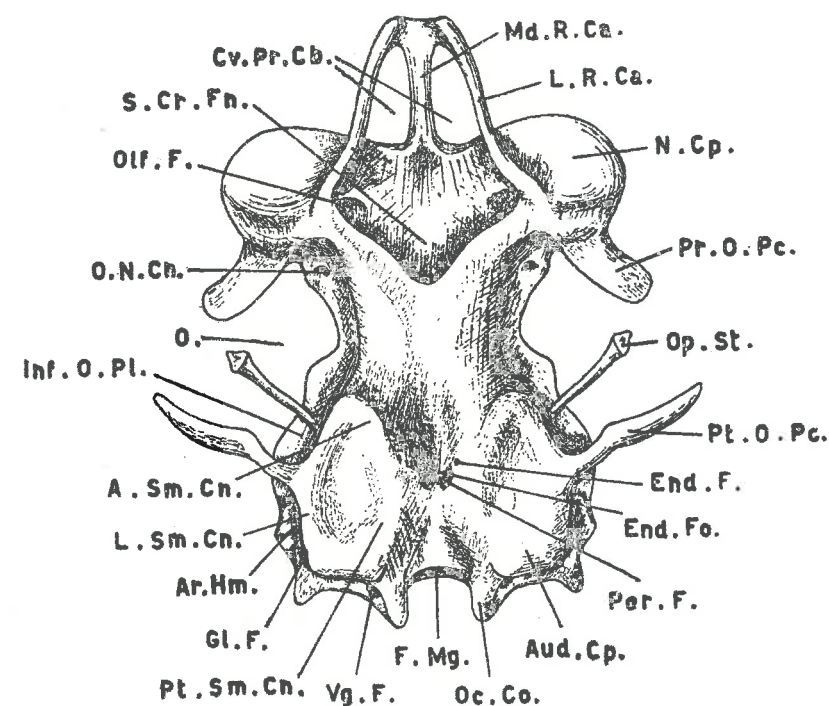
At the anteriormost end of the orbital cartilage lies the posterior opening of the orbitonasal canal (O.N.Cn.) through which the anterior facial vein passes to join the orbital sinus.

Ventrally, the floor of the neurocranium (Text-fig. 43) is formed of the trabecular plate (T. Pl.) anteriorly and the parachordal plate (Pa. Pl.) posteriorly. The position of the internal carotid foramina (I. C. F.) indicates the limit between the two plates which is here not otherwise distinct. The trabecular plate curves upwards toward the internasal region where it curves downwards forming the subethmoidal depression. Anterior to this region, the prolongation of the trabecular plate leads to the formation of the median rostral cartilage (Md. R. Ca.). The parachordal plate, slightly curving downwards, extends laterally to fuse with the auditory capsule. The ventral surface of the occipital arch lies in a level somewhat dorsal to the ventral surface of the auditory capsules. The nasal aperture (N. Ap.) is nearly oval in shape and lies on the ventral surface of the neurocranium. At its postero-median edge is the wide olfactory foramen (Olf. F.) through which the olfactory nerve passes to the nasal capsule. Nearly the anterior three quarters of the nasal aperture are occupied by an arch-like nasal cartilage (N. Ca.), the rest being covered with tight connective tissue. Both the cartilage and the connective tissue are firmly attached to the inner edge of the nasal capsule. The two limbs of the nasal cartilage meet each other medially, and from each limb extends a tapering process which meets the process of the other, thus separating the nasal aperture into two portions; one for the inhalent and the other for the exhalent currents.

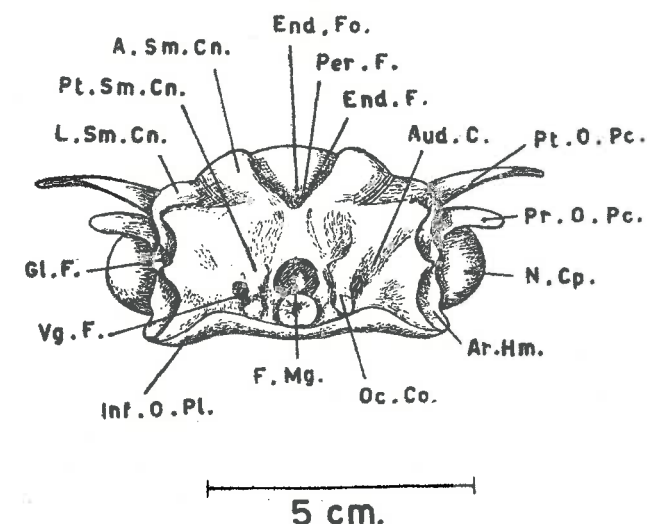
The lateral edge of the posterior surface of the neurocranium (Text-fig. 44) is formed by the well developed articular surface for the hyomandibular (Ar. Hm.), at the dorso-median edge of which is found the external opening of the glossopharyngeal foramen (Gl. F.). Just lateral to the occipital condyles (Oc. Co.), lies a wide foramen transmitting the vagus nerve (Vg. F.). *Aprionodon acutidens*, where the hyomandibular articular facet is largely developed, supplies further corroboration to Allis' view (1923) concerning the posterior position of the glossopharyngeal and vagus foramina.

The occipital condyles are well developed and separated by a rounded concavity which lies below the foramen magnum (F. Mg.) and shares in the occipito-vertebral articulation.

The median wall of the neurocranium (Text-fig. 45) is provided with a somewhat deep fossa, the acustico-trigemino-facialis recess (Ac. Tr. Fa. Rec.). This recess lies posterior to the facial foramen and lodges the proximal portion of the trigeminal, facial and auditory nerve ganglia. At the antero-dorsal edge of the acustico-trigemino-facialis recess is found a small foramen for the saccular division of the auditory nerve (Sac. F.). In front of this foramen lies another small foramen through which passes the vestibular division of the auditory nerve (Ves. F.).

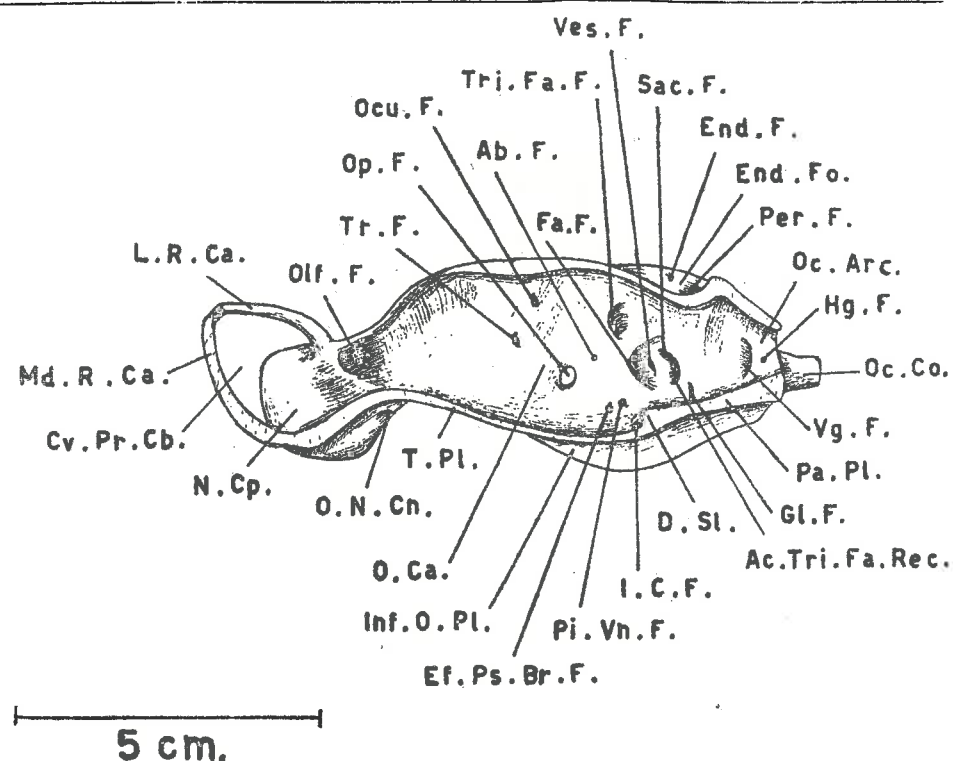


Text-fig. 43 : *Aprionodon brevipinna*. Ventral view of neurocranium.  
(Nasal cartilage of left side removed).



Text-fig. 44 : *Aprionodon brevipinna*. Posterior view of neurocranium.



Text-fig. 45 : *Aprionodon brevipinna*. Median view of neurocranium.

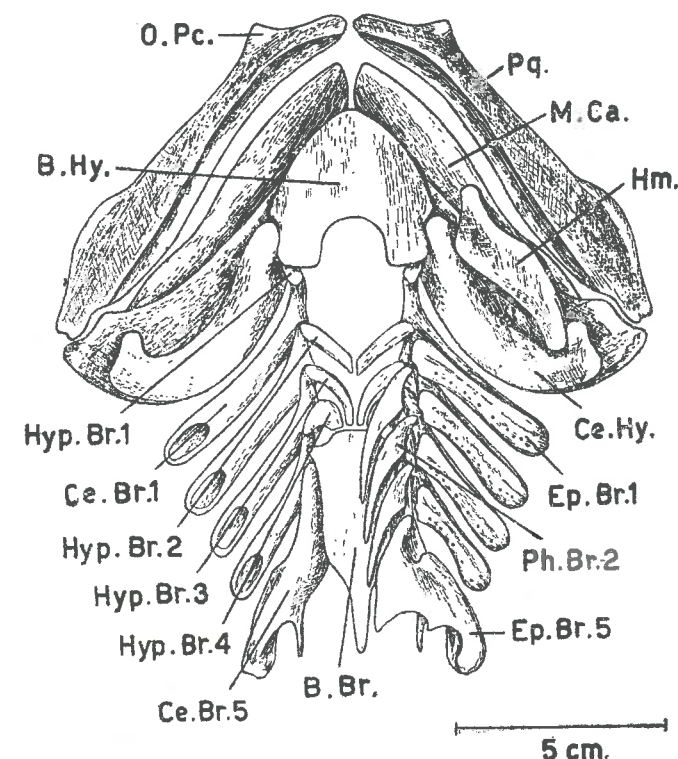
The inner glossopharyngeal foramen (Gl. F.) lies a little posterior to the ventral border of the acustico-trigemino-facialis recess. At a considerable distance from this foramen is the much larger vagus foramen. The glossopharyngeal and vagus foramina lie nearer to each other in the lateral view than they are in the median, due to the fact that the glossopharyngeal nerve does not go directly out of the neurocranium, as does the vagus nerve, but passes within the glossopharyngeal canal traversing the auditory capsule.

The occipital arch (Oc. Ar.) is pierced by one hypoglossal foramen (Hg. F.), through which a cranial root of the hypoglossal nerve passes.

#### B.—The Viscerocranium of *Aprionodon brevipinna* :

The viscerocranium of *Aprionodon brevipinna* (Text-fig. 46) is composed of the mandibular, hyoid and five branchial arches.

The mandibular arch is relatively greatly developed and much larger than the rest. The basimandibular is missing. The palatoquadrate is relatively much more firmly united than Meckel's cartilages, with which it articulates by two special articulating parts. The articular part of the palatoquadrate is convex and forms a peg which fits in the socket-like articulating surface of Meckel's cartilage.

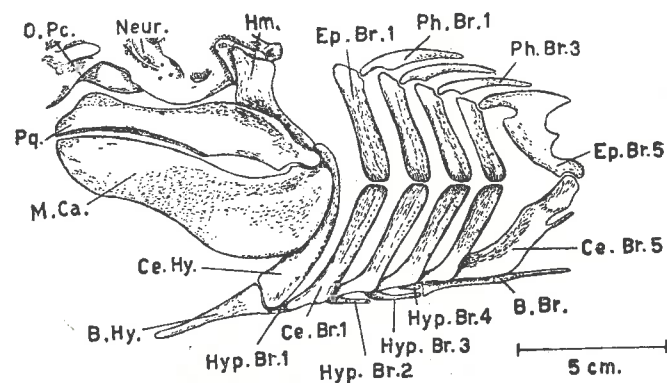
Text-fig. 46 : *Aprionodon brevipinna*. Dorsal view of visceral skeleton. (Hyomandibular, pharyngobranchials and epibranchials of left side removed, hyal and branchial rays omitted from arches).

The palatoquadrate is provided with a massive orbital process (O. Pc.) which articulates with the lateroventral border of the neurocranium, somewhat posterior to the hind wall of the nasal capsule (Text-fig. 47). This articulation is not a palato-basal one, the otic process is missing, and the weight of the jaws is carried by the hyomandibular cartilage, leading to a hyostylic type of jaw suspension.

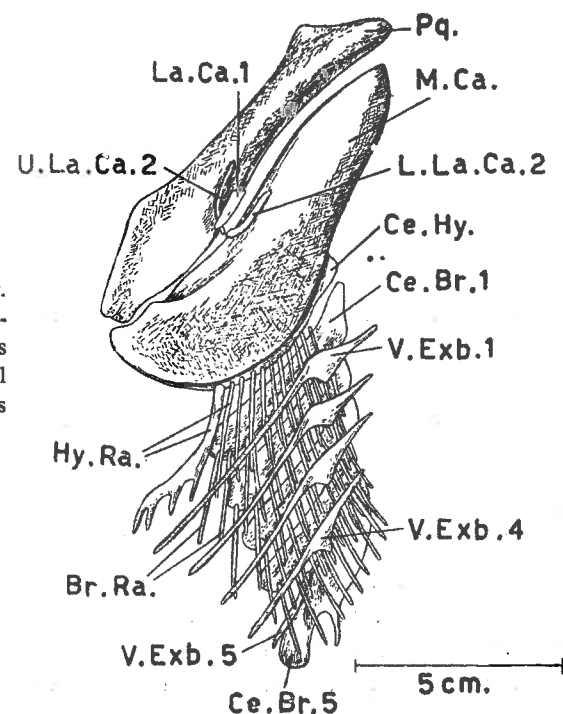
The spiracular cartilages are completely missing in *Aprionodon brevipinna*.

The ceratohyal (Text-fig. 48, Ce. Hy.) and hyomandibular (Text-fig. 49, Hm.) are provided with cartilaginous hyal rays (Hy. Ra.). One or more of the inner hyal rays are detached from their corresponding elements, while the outer ones are generally fused near their bases, forming one main stalk carrying several branches.

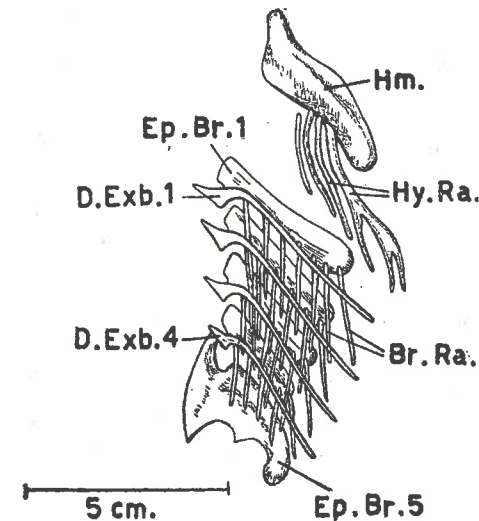
All the five branchial arches, except the last, bear cartilaginous branchial rays on their epi- and cerato-branchial elements.



Text-fig. 47 : *Aprionodon brevipinna*. Lateral view of visceral skeleton. (Ventral elements pulled downwards. Hyal and branchial rays omitted from arches).



Text-fig. 48 : *Aprionodon brevipinna*. Ventral view of palatoquadrate, Meckel's cartilage, ceratohyal and ceratobranchials of right side.



Text-fig. 49 : *Aprionodon brevipinna*. Dorsal view of hyomandibular and epibranchials of right side.

The fourth and fifth pharyngobranchials are fused together forming a large, flattened plate, the compound nature of which can be easily traced by the existence of two points separated by a ventral groove terminating in a notch. The anterior tip of this plate corresponds to the fourth pharyngobranchial, while the posterior corresponds to the fifth. With this compound plate, the fifth epibranchial (Ep. Br.5) is completely fused.

Four pairs of hypobranchials are represented, and they are related to the first (Hyp. Br. 1), second (Hyp. Br.2), third (Hyp. Br. 3) and fourth (Hyp. Br. 4) branchial arches. Only the fifth hypobranchials are lacking. The articulation between the hypobranchials and their corresponding ceratobranchials takes place by the anterior processes of the inner edges of the latter elements. The first hypobranchial is relatively much reduced and located between the first ceratobranchial (Ce. Br. 1) and the latero-posterior border of the basihyal (B. Hy.).

The second hypobranchials extend medially from their ceratobranchials approaching each other more closely due to the absence of a corresponding basibranchial. The third and fourth hypobranchials, on the other hand, extend posteriorly to join the anterior border of the large, flattened basibranchial (B. Br.).

The three labial cartilages (Text-fig. 48) are present and have similar structure and position.

The extrahyal cartilages are lacking, and the extrabranchials are represented by five ventral and four dorsal elements (Text-figs. 48 and 49). The similarity of the fifth ventral extrabranchial, in shape and position, to the ordinary branchial rays supports Gegenbaur's view (1872) considering the extrabranchial cartilages as modified branchial rays.



## IV.—CONCLUSION

Authors differ in considering whether sharks or rays are more primitive, but the studies of the development of elasmobranchs, such as *Scyllium* (Balfour, 1876-78, Sedgwick, 1892, Goodrich, 1918), *Acanthias* (Scammon, 1911), *Torpedo* (Balfour 1876-78), *Rhinobatus halavi* and *Rhynchobatus djiddensis* (Melouk, 1949), and *Carcharinus melanopterus* (Melouk, 1957) show that the selachoids and batoids pass during their early development through a generalized stage having lateral gill-slits and paired fins in the postbranchial regions. In the following stages, the gill-slits remain lateral and the pectorals develop at the same position in selachoids. On the other hand, batoids proceed to a transitional phase whose body approaches that of *Squatina* (transitional shark), viz., the gill-slits have a lateroventral position and the pectoral fins extend forward and backward encroaching on the branchial region but not yet fused with the head through the branchial crests. Lastly, a more specialized phase is reached in which the gill-slits are completely ventral and the pectoral fin fuses with the sides of the head. This shows that sharks are more primitive and rays have acquired secondary adaptation to bottom-life.

The liver is relatively much larger and more oily in sharks than in rays. Thus, it weighed 18%, 17%, 8%, 6%, 4.5 % and 2% of the body weight respectively in *Galeocерdo cuvier*, *Nebrius concolor*, *Manta ehrenbergi*, *Aetobatus narinari*, *Teniura lymma* and *Rhinobatus halavi*. *G. cuvier* which is most active, yielded 444 gm. oil per one kilogram of liver, while *R. halavi*, which is a bottom living batoid yielded 200 gm. oil per kilogram of liver. Such massive and oily livers in the active pelagic sharks may aid in their flotation.

It is worth-mentioning here that in *Mobula* — in contrast to all other described species— the duodenum is markedly elongate and the bile duct opens at the posteriormost portion of the bursa entiana preceding the narrow long duodenum, while the pancreatic duct opens at the end of the duodenum at its junction with the valvular intestine.

The valvular intestine is characteristic for elasmobranchs, and three types of valve have been described, viz. : the scroll, the spiral, and the ring types (White, 1937). In *Rhynchobatus djiddensis* and *Rhina ancylostoma* (Fam. Rhynchobatidae) the valve of the intestine follows two types of folding, the first is a spiral type extending along the middle axis of the intestine ; while the second is of the ring type where annular rings arise separately from the walls of the intestine around and in between the successive turns of the spiral valve. Such a type of valve has not been described before and it is proposed here to call it the spiro-annular type.

The heart differs in size in the different species of the elasmobranchs, not only according to the size of the animal, but also according to the mode of life and activity. Thus, in the shark *Mustelus canis* as well as in the ray *T. lymma* and the transitional form of batoid *R. halavi* the heart is relatively small and its size suits the limited activity of these bottom inhabitants. On the other hand, the heart is large, greatly developed and strongly muscular in the strong, free living shark *G. cuvier* and the fast swimmer ray *A. narinari*. This is evidently an adaptation to the great activity of these animals.

The auricle is a thin-walled distensible bag which receives the non-oxygenated blood from the sinus venosus, the sinu-auricular valves project into the sinus venosus; thus permitting the free passage of blood into the auricle and preventing its back-flow. The auriculo-ventricular valve has four cusps in all the selachoids and batoids examined here, though Daniel (1934, p. 171) stated that this valve consists in elasmobranchs of two pocket-like flaps. Usually and especially in sharks, which are active swimmers, the ventricle is large, thick and highly muscular, with a spongy internal surface and a narrow cavity, thus spelling immense power to push the blood throughout the large active body.

In all elasmobranchs the conus arteriosus is muscular and functional. It is short in the examined Selachii, but rather long in the batoids. The myocardial layer ends opposite to the valves of the first series. The valves of the conus are constructed on a common plan in all elasmobranchs, as they are arranged in three well-developed longitudinal rows, one dorsal and two latero-ventral. The anterior-most set of valves has the largest and strongest pockets reaching the base of the ventral aorta and perfectly designed to prevent the back-flow of blood from the aorta to the conus.

The number of valves in the conus arteriosus, has been subject of discussion from time to time. Garman (1885) suggests that the large number of valves is a primitive character and that reduction has occurred in the sharks with the increase in specialization, and he adds that in the rays the rule does not hold so well. This opinion has been generally accepted by Daniel (1928). In contrast to this view, White (1937) stated that «In the Platosomae, the number, of tiers in each longitudinal row is rather increased, reaching six and sometimes seven, but in some species they are very few in number. The tendency in the elasmobranchs is for duplication of valves rather than reduction, and this duplication may take place transversely as well as longitudinally ».

The problem of the number of valves has been studied here in the different species of elasmobranchs present in our locality. It has been found that in the

sluggish sharks *Nebrius concolor* and *Stegostoma fasciatum*, the number of valves in each row is two, and duplication occurs longitudinally, as a fourth row, though accessory, has been found in *N. concolor*. Also, *Carcharhinus melanopterus*, *C. maculipinnis*, *C. sorrah*, *C. albimarginatus* (all from the Carcharhinidae) have only two valves in a row. Three valves are found in the sharks *G. cuvier*, *C. longimanus*, *S. walbeehmi*, *S. palasorrah*, *T. obesus*, *Heterogaleus ghardagensis* (Carcharhinidae), and *M. canis* (Triakidae). The transitional selachoid, *Squatina squatina*, has seven cusps (Marples, 1936).

The ray *Torpedo panthera* (Torpedinidae) possesses four valves ; while *Taniura lymma*, as well as the transitional batoids *Rhinobatos*, *Rhynchobatus* and *Rhina* possess five cusps in a row. Six valves are found in the rays *D. uarnak*, *D. sephen* and *Manta ehrenbergi*. The number of valves increases to eight in the highly specialized ray *A. narinari*, though White (1937) gave the number in this last mentioned ray as only five.

From this, it may be concluded that among batoids the number of valves is small in sluggish and bottom living individuals, increasing with the advance of specialization and the activity of swimming but concerning the selachoids no definite statement can be made. However, it is clear that the number of valves increases from the Selachioidei towards the Batoidei.

In *G. cuvier*, the four afferent branchial arteries arise separately from the ventral aorta, while *N. concolor* has a short posterior trunk which divides into the fourth and third afferent arteries. The latter condition resembles those described in *D. dipterura* by Daniel (1934) and in the transitional form of shark, *Squatina* by Marples (1936). The rays, *T. lymma*, *A. narinari*, *D. uarnak* and *D. sephen* have been found to be, in this respect, similar to *G. cuvier*, contrary to Daniel (1934) who stated that in rays in general, two stems leave the ventral aorta to give rise to the afferent branches. Daniel's description, however, applies to the transitional batoids, *R. halavi*, *R. djiddensis*, and *Rhina ancylostoma* in which two trunks arise from the ventral aorta.

It can thus be concluded that the afferent arteries have no definite arrangement in their mode of origin in sharks or rays.

In all our species, except in *R. halavi* where a single trunk carries the supply of the first, second and third epibranchial arteries to the dorsal aorta, the epibranchial arteries open independently into the dorsal aorta.

The coronary arteries are well-developed in all the species dealt with here and especially in the strong pelagic shark *G. cuvier*, as well as the actively swimming ray *A. narinari*, the demand of the heart muscles for oxygenated blood being here particularly high.

The distribution of the coronary arteries differs, not only from one species to another, but also sometimes in the different individuals of the same species ; and this agrees with the view expressed by Grant and Regnier (1926). The blood for these coronary arteries is derived from the hypobranchial arterial vessels. Foxon (1950)) stated that «such blood may be drawn either : (1) from the more anterior region of the ventral ends of the efferent loops or (2) from a more posterior origin in the region of the subclavian arteries», all our species, however, agree with Foxon's first category as the coronary arteries reach the heart from the more anterior region.

The point of origin of the subclavian from the dorsal aorta differs from one species to another. It originates at the base of the third pair of epibranchials in *Galeocerdo cuvier* ; while a considerable distance posterior to the fourth pair of epibranchials in *Nebrius concolor*. In *Taniura lymma*, the subclavian originates just anterior to the fourth epibranchial ; while in *Aëtobatus narinari* it is given a considerable distance anterior to the fourth epibranchial. In *R. halavi*, it arises at the base of the fourth epibranchial.

The branching system of the brachial artery to supply the pectoral fins differs in sharks from that in rays. Thus, in the sharks *G. cuvier*, and *Nebrius concolor* the brachial artery divides into two relatively thin branches, a median pterygial artery and a lateral artery. While in rays, e. g. *A. narinari* and *T. lymma*, the brachial artery is stronger and divides into an anterior well-developed propterygial artery and a posterior strong metapterygial artery and either the former or the latter gives rise to a strong third branch.

It is evident that in the above-described cases, the brachial supply is adapted to the activity of the pectoral fins, which in the Selachioidei are not used for locomotion and show no special development of the muscles, and thus no special provision for copious blood supply is required. In contrast, in the Batoidei where the tail has almost completely lost the propulsive function, the propulsion of the body having been taken over mainly by the pectoral fins which are greatly developed for this purpose, their musculature has tremendously grown and accordingly requires special provision for a copious blood supply.

The urinogenital system in both sexes is built up in the sharks and rays examined on the same general plan, as in most other elasmobranchs. As usual in elasmobranchs, there is a marked sexual difference in the kidneys. Such a difference appears in the reduction of the anterior part of the kidney in the female, which in the adult male, is developed for the service of the genital system into «Leydig's gland».

In the case of *G. cuvier*, *N. concolor*, *T. lymma*, *Aëtobatus narinari*, *Rhinobatos* and *Rhynchobatus* females possess two ovaries. The left ovary is more developed than the right in *T. lymma* ; while the right ovary is more developed than the left in *N. concolor*. Both oviducts open into the body cavity by a single oviducal opening



in *G. cuvier*, *R. halavi*, and *R. djiddensis* and by two independent oviducal openings in *N. concolor*, *T. lymma*, and *A. narinari*. In *T. lymma* and *A. narinari*—in contrast with the other four described species—only the left uterus is functional.

The shell-gland is relatively better developed in the ovo-viviparous, *N. concolor* and *R. djiddensis*. In the uterus of an adult individual of the former shark four thick brownish empty horny shells were found in March. The embryos pass all their developmental stages in the egg-case within the mother, before the young are born. Also, four large thin-walled egg-cases (full of yolk) of golden yellow colour were found in each uterus of a pregnant female *Rhynchobatus* (on 10 June). Another pregnant individual of the same species delivered four young in October 1959 while in the vivarium.

In December, 44 embryos (ranging from 52 to 54 cm. in length) were found in the two uteri of a pregnant individual of *Galeocerdo cuvier*, and each foetus was provided with a large external and a small internal yolk-sac, and the ducts of the two sacs emptied into the duodenum. This number of embryos seems to be the record for all elasmobranchs.

In August, one female *Tæniura lymma* gave birth to a single young, and another gave two in the aquarium.

Eight to ten embryos were usually found in the uteri of pregnant *R. halavi* (between May and October) and each uterus had half the number of embryos.

No oviparous species has so far, been encountered in the Red Sea, but some of the species are ovo-viviparous while others are viviparous. The lining of the uterus in such types is not smooth, as that of oviparous types, but is rather complicated by special development to help in the nutrition of the foetus. Thus, the uterus is provided with low folds in the ovo-viviparous *Rhinobatos halavi*, *Rhynchobatus djiddensis* and *Nebrius concolor*; or thrown into highly vascular long papillae as in *T. lymma* and *Aëtobatus narinari*; or form longitudinal compartments as is the case in the viviparous, *Mustelus canis*. In *T. lymma*, the papillae of the uteri were seen in the spiracles of the embryo; and a creamy liquid, probably secreted by the uterine lining, was found in the intestine of the latter. In other species (viviparous), which have long navel-cords such as *M. canis*, *Carcharhinus maculipinnis* and *C. sorrah*, the yolk sac is embedded in the wall of the uterus and its surface is much convoluted, and through this attachment nutriment may be secured by the embryo.

In the examined sharks, *G. cuvier* and *N. concolor*, where the cranium is greatly calcified, hard, elongate and laterally compressed, the brain is elongate rather laterally compressed and occupies the posterior half of the brain case, the anterior half being filled with a thick gelatinous matter. On the other hand, in the dorsoventrally depressed and rather broad skull of rays (e.g. *A. narinari* and *T. lymma*) the

brain is also flattened and becomes larger, broader and heavier than that of sharks, filling most of the cavity of the brain-case.

In *A. narinari* the brain is especially large and surrounded by a large mass of hyphae-like connective tissue, this is probably a means of protection as the brain lies, nearly wholly, under the large wide supracranial fontanelle.

The brain, in *R. halavi* and *R. djiddensis*, shows a transitional form between those of sharks and rays, as in those forms it occupies a rather posterior position in the brain-case as in sharks, but it is rather broad as in the case of rays.

The pituitary body is developed in the examined species, as is the usual case in elasmobranchs, although it is especially highly developed in *G. cuvier*. The saccus vasculosus which is believed to be particularly well developed in deep-sea fish and is thought to be a pressure receptor (Dammerman, 1910) is better developed in *G. cuvier* than in the shallow water benthic shark, *N. concolor*, and the shallow water bottom-living rays. It may be remembered that *G. cuvier* is a pelagic shark capable of descending to considerable depths.

The relative size and the gross shape and structure of the cerebellum vary greatly in sharks and rays. It is poorly developed and fairly smooth in pelagic sharks such as *Galeocerdo*, but tends to be lobulated in bottom-living sharks like *Nebrius*. It is better developed in *Rhynchobatus* and *Rhinobatos* and reaches its maximum size and complexity in the highly specialized rays like *Aëtobatus* and *Manta*, where the flattening of the body reaches its maximum, and the sense of equilibrium and posture becomes important. The degree of development of the optic and the oculomotor nerves agrees with the development of the eyes and eye-sight. These nerves are best developed in strong swimmers, such as *Galeocerdo* and *Aëtobatus*, where sight is most needed. They are moderately developed in the benthic *T. lymma*, *Rhynchobatus* and *Rhinobatos* and poorest in the sluggish and nocturnal shark, *Nebrius*, which has small and poorly developed eyes.

## V.—SUMMARY

1. The anatomy of the main systems of six representative species of the Red Sea elasmobranchs: *Galeocerdo cuvier*, *Nebrius concolor*, *Rhinobatos halavi*, *Rhynchobatus djiddensis*, *Tæniura lymma* and *Aëtobatus narinari* together with the previously studied *Mobula kühlii* is given. The gut is expectedly short in all species studied as they are all typically carnivorous. The only exception is afforded by the family Mobulidae and particularly *Mobula* which are mainly plankton-feeders; both the bile duct and the pancreatic duct open into the short segment preceding the valvular intestine. And where the gut is comparatively long, the bile duct opens at the end of the bursa entiana at its junction with the duodenum, while the pancreatic duct opens at the end of the duodenum where the latter passes into the valvular intestine.

2. A new type of intestinal valve, a spiro-annular type, has been met with in *Rhynchobatus djiddensis* and *Rhina ancylostoma* and is described.

3. The heart and the main blood vessels are dealt with. The coronary arteries are well developed in elasmobranchs especially in active swimmers like *Galeocerdo cuvier*. The conus valves increase in number from sharks towards specialized rays.

4. The urinogenital system of both sexes is described in the six species. The number of embryos, size, season, etc., are recorded. The maximum number met with was 44 fully developed embryos in a female *Galeocerdo cuvier*. The relation of embryos to the mother uteri is discussed.

5. The brain has the general form of the brain-case being narrow and elongated in sharks, broad and occupying a large part of the cranium in rays. The cerebellum is simpler in sharks than in rays, reaching maximum complexity in highly specialized rays. The pituitary as well as the saccus vasculosus are highly developed in *Galeocerdo cuvier*.

6. A detailed study of both neurocranium and viscerocranium of *Aprionodon brevipinna* (belonging to Selachioidei) is given. The relations of the hyoid and branchial arches to their corresponding blood vessels is studied in *Carcharhinus melanopterus* (selachoid form), *Tæniura lymma* (batoid form), and *Rhynchobatus djiddensis* (transitional form).

The hyoid arch of *A. brevipinna* is formed of two segments, a dorsal hyomandibular and a ventral ceratohyal, while in *Rhynchobatus djiddensis* it is formed of the hyomandibular, ceratohyal, dorsal pseudohyoid bar and ventral pseudohyoid bar. In *Tæniura lymma* the hyoid arch is similar to that of *R. djiddensis*, but the ceratohyal is completely missing. The basihyal is present in all of these selachians.

In *A. brevipinna* there are five pharyngobranchials, the last two are fused together but no connection between the pharyngobranchials and the vertebral column exists.

The four hypobranchials are present the fifth being missing. There are three labial cartilages in *A. brevipinna*.

#### LIST OF ABBREVIATIONS

*Ab. N. V1*, Abducens nerve; *Abd. C.*, Abdominal cavity; *Abd. pr.*, Abdominal pore; *Aff. Ar. 1, 2, 3, 4*, First, second, third and fourth afferent branchial arteries; *Aff. Tr. 2*, Second afferent trunk; *Al. Vc. Op.*, Auriculo-ventricular opening; *Al. Vc. Va.*, Auriculo-ventricular valve; *Aor. d.*, Dorsal aorta; *Aor. V.*, Ventral aorta; *At.*, Atrium; *Aud. N. VIII*, Auditory nerve; *Bc. F.*, Buccal fold; *Bc. R.*, Buccal roof; *Br. A.*, Branchial arch; *Br. Kb.*, Branchial knobules; *Br. Op. in.*, Branchial internal opening; *Brc. Ar.*, Branchial artery; *Bs. En.*, Bursa entiana; *C.*, Caecum; *Cad. Vn.*, Cardinal veins; *Cd. Rg.*, Cardiac ridges; *Cd. St.*, Cardiac stomach; *Cd. St. In.*, Lining of cardiac stomach; *Ce. Cn.*, Central canal; *Cer.*, Cerebellum; *Ch. Pl. a.*, Anterior choroid plexus; *Cl.*, Cloaca; *Cls.*, Clasper; *Co.*, Colon; *Cod. Ar.*, Coracoid artery; *Cod. Ar. mn.*, Main coracoid

artery; *Coe. Mes. Ar.*, Coeliaco-mesenteric artery; *Com. Ar.*, Commissural artery; *Com. Ar. Eff. 9*, Commissural artery of the last (ninth) efferent collector; *Con. Art.*, Conus arteriosus; *Cop. Str.*, Corpus striatum; *Cord. Td.*, Chordae tendinae; *Corp. Res.*, Corpora restiforme; *Cr. Ar. d.*, Dorsal coronary artery; *Cr. Ar. d. br.*, Dorsal branch of coronary artery from coracoid; *Cr. Ar. 1.*, Left coronary artery; *Cr. Ar. med.*, Median coronary artery; *Cr. Ar. 1. br.*, Coronary artery left branch from coracoid; *Cr. Ar. 1t. br.*, Lateral branch of left coronary artery; *Cr. Ar. med.*, Median coronary artery; *Cr. Ar. med. br.*, Median branch of right coronary artery; *Cr. Ar. mn.*, Main coronary artery; *Cr. Ar. r.*, Right coronary artery; *Cr. Vn. 1.*, Left coronary vein; *Cr. Vn. med.*, Median coronary vein; *Cr. Vn. r.*, Right coronary vein; *Cr. V1. v.*, Ventral coronary vein; *Ct. Tb.*, Collecting tubule; *D. ch.*, Ductus choledochus; *D. Ch. Op.*, Ductus choledochus opening; *Din. Rf.*, Diencephalon roof; *Dsl. Ar. a.*, Anterior dorso-lateral artery; *Dsl. Ar. p.*, Posterior dorso-lateral artery; *Du.*, Duodenum; *Ebr. Ar. 1-4*, First, second, third and fourth epibranchial artery; *Eff. Col. 9*, Ninth efferent collector; *Eff. Col. a.*, Anterior efferent collectors; *Ep.*, Epigonal body; *Ep. 1.*, Left epigonal body; *Ep. r.*, Right epigonal body; *F.*, Folds; *F. cr.*, Circular folds; *F. lg.*, Longitudinal folds; *F. mid.*, Middle fold; *F. ob.*, Oblique fold; *Fac. N. VII*, Facial nerve; *Gd. Ar.*, Artery supplying gonad; *Glos. IX.*, Glossopharyngeal; *Gs. Ch. Om.*, Gastro-choledochic omentum; *Gs. Du. Om.*, Gastro-duodenal omentum; *Gs. Mes.*, Gastric mesentery; *Gs. Pa. Ms.*, Gastropancreatic mesentery; *Gs. Spl. Om.*, Gastro-splenic omentum.

*Hp. Pa. Vn.*, Hepato-pancreatic vein; *Hy. Ar.*, Hyoidean artery; *Hyp. Ar. 1t.*, Lateral hypobranchial artery; *Hyp. Ar. med.*, Median hypobranchial; *In. Du. Op.*, Internal opening to duodenum; *Inf. lo.*, Inferior Lobe; *Infm.*, Infundibulum; *Int.*, Intestine; *Int. Va.*, Valvular intestine; *Ko.*, Knobules; *Lp. 1.*, First loop; *Lv. 1o. 1.*, Liver left lobe; *Lv. 1o. md.*, Liver middle lobe; *Lv. 1o. r.*, Liver right lobe; *M.*, Mamilla; *Md. Va.*, Mandibular valve; *Mdl. Ob.*, Medulla oblongata; *Mes. Ch.*, Choledochic mesentery; *Mes. F. mid.*, Middle mesenteric fold; *Mes. F. 1.*, Left mesenteric fold; *Mes. Rc.*, Mesorectal; *Mem.*, Membranous part of first set of valves; *Mn.*, *Cod. Ar.*, Main coracoid artery; *Mptg. Ar.*, Metapterygial artery; *Msc.*, Mesorchium; *Msn.*, Mesonephros; *Msn. a.*, Mesonephros anterior lobe; *Msn. P.*, Mesonephros posterior lobe; *Msg.*, Mesogastrium; *Msov.*, Mesovarium; *My. 1.*, Inner myocardial layer; *My. o.*, Outer myocardial layer; *My. Vc.*, Myocardial wall of ventricle; *Mx. Va.*, Maxillary valve; *N. C.*, Nasal curtain; *N. S.*, Nasal septum; *Mr. R.*, Neuroporic recessus; *Ns.*, Nostril; *O.*, Ova; *Oc. Sp. d.*, Dorsal root of occipito-spinales nerve;

*Oc. Sp. V.*, Ventral root of occipito-spinales nerve; *Ocu. N. III*, Oculomotor nerve; *Oes.*, Oesophagus; *Ces. In.*, Oesophageal lining; *Oes. Mes.*, Oesophageal mesentery; *Oes. Ms.*, Muscular wall of oesophagus; *Ol. b.*, Olfactory bulb; *Ol. Io.*, Olfactory lobe; *Ol. N. med.*, Median olfactory nucleus; *Ol. Tr.*, Olfactory tract; *Opt. Chs.*, Optic chiasma; *Op. Cr. Vn. v.*, Opening of ventral coronary vein; *Opt. Io.*, Optic lobe; *Opt. N. II*, Optic nerve; *Or. pp.*, Oral papillae; *Os. Ut.*, Os uterus; *Ov. r.*, Right ovary; *Ovd.*, Oviduct; *Ovd. Ar.*, Oviducal artery; *Ovd. Op.*, Oviducal opening; *Ovd. Va.*, Oviducal valve; *Pa. D.*, Pancreatic duct; *Pa. D. Op.*, Opening of pancreatic duct; *Pa. Lo. d.*, Dorsal lobe of pancreas; *Pa. Lo. V.*, Ventral lobe of pancreas; *Pal. Em.*, Pallial eminences; *Pal. Su.*, Pallial sulcus; *Per. Ar.*, Pericardial artery; *Pit.*, Pituitary; *Pit. a. Lo.*, Pituitary anterior lobe; *Pit. m. Lo.*, Pituitary middle lobe; *Pit. Pl. Lo.*, Pituitary postero-lateral lobe; *Pit. Sup. Lo.*, Pituitary superior lobe; *Pl.*, Papillae; *P. pp.*, Posterior papillae; *ptg. Ar.*, Propterygial artery; *Ps. H.*, Parasitic Hirudinea; *Ptg. Ar. lt.*, Lateral pterygial artery; *Ptg. Ar. med.*, Median pterygial artery; *Pv. Fn. 1.*, Left pelvic fin; *Py. F.*, Pyloric folds; *Py. Bg.*, Pyloric bulge; *Py. Rg.*, Pyloric ridges; *Py. V. Rg.*, V-shaped pyloric ridge;

*Py. Va.*, Pyloric valve; *Py. St.*, Pyloric stomach; *R. Anl.*, Annular ring; *R. F. inc.*, Incomplete ring fold; *Rc.*, Rectum; *Rc. G.*, Rectal gland; *Rc. G. Op.*, Opening of rectal gland; *Rg. ir.*, Irregular ridges; *Rg. 1.*, Lateral ridge; *Rg. 1g.*, Longitudinal ridge; *Rg. mid.*, Middle ridge;



*Rg. ob.*, Oblique ridge; *S. Lg.*, Suspensory ligament; *Sbc. Ar.*, Subclavian artery; *Sc. Va.*, Scroll valve; *Sep. t.*, Transverse septum; *Sh. Gl.*, Shell-gland; *Sh. Gl. Ms.*, Muscular wall of shell-gland; *Sm. Sc.*, Sperm-sac; *Sm. Sc. Op.*, Sperm-sac opening; *Sn. Al. Op.*, Sinu-auricular opening; *Sn. Al. Va.*, Sinu-auricular valve; *Sp. In.*, Spiral intestine; *Sp. Va.*, Spiral valve; *Sp. Va. 1-4*, Spiral turns of valve 1-4; *Spl.*, Spleen; *Spl. Pa. Om.*, Spleno-pancreatic omentum; *Spn. C.*, Spinal cord; *Spc. Op. in.*, Internal spiracular opening; *T. Bd. Lw.*, Lower tooth-band; *T. Bd. up.*, Upper tooth-band; *T. up.*, Upper tooth; *Tg.*, Tongue; *Tr. Sep.*, Transverse septum; *Trig. V.*, Trigeminal nerve; *Tro. N.*, Trochlear nerve; *Ts.*, Testis; *Ts. l.*, Left testis; *Ts. r.*, Right testis; *Ug. pp.*, Urinogenital papilla; *Ug. Sn.*, Urinogenital sinus; *Un. pp.*, Urinary papilla; *Un. Sn.*, Urinary sinus;

*Ur.*, Ureter; *Ur. D.*, Urinary duct; *Ur. Op.*, Opening of ureter; *Ut. In.*, Lining of uterus; *Ut. Op.*, Opening of uterus; *Ut. r.*, Right uterus; *V. Def.*, Vas deferens; *V. Eff.*, Vas efferens; *Va.*, Valve; *Va. 1-8*, First to eighth valve; *Va. II*, Secondary valve; *Va. Int.*, Valvular intestine; *Va. an. T.*, Anterior turns of valve; *Va. Po. T.*, Posterior turns of valve; *Vg.*, Vagina; *Vag. X*, Vagus nerve; *Vas. Sc.*, Vascular sac; *Vc.*, Ventricle; *Vc. Iv.*, Fourth ventricle; *Vi.*, Villi; *Va. Sm. Op.*, Opening of vesicula seminalis; *W. D.*, Wolffian duct;

## VI.—REFERENCES

- ALCOCK, A. (1890) : Some Observations on the Gestation of some Sharks and Rays. Jour. Asiatic Soc. Bengal, V. 59.
- ALLIS, E. P. (1913) : The homologies of the ethmoidal region of the selachian skull. Anat. Anz., V. 44, pp. 322-328.
- — — (1914 a) : Certain homologies of the palatoquadrate of selachians. Anat. Anz., V. 45, pp. 353-373.
- — — (1914 b) : The pituitary fossa and trigemino-facialis chamber in selachians. Anat. Anz., V., 46, pp. 225-325.
- — — (1919) : The lips and the nasal apertures in the gnathostome fishes. Journ. Morph., V. 32.
- — — (1923) : The cranial anatomy of *Chlamydoselachus anguineus*. Acta Zoologica, V. 4, pp. 123-221.
- BALFOUR, F. M. (1876-78) : Monograph on the Development of Elasmobranch Fishes. London.
- — — (1881) : On the Development of the Skeleton of Paired Fins of Elasmobranchii, considered in Relation to its Bearings on the Nature of the limbs of Vertebrates. Proc. Zoo. Soc. London.
- BOULENGER, G. A. (1922) : Fishes and Ascidians. Cambridge Natural History. V. 7.
- DAMMERMAN, K. W. (1910) : Der Saccus vasculosus der Fische ein Tiefeorgan. Z. Wiss. Zool. 96, 654-726.
- DANIEL, J. F. (1915) : The anatomy of *Heterodontus francisci* II The endoskeleton. Journ. Morph., V. 26.
- — — (1928) : The Elasmobranch Fishes. Univ. California press.
- DE BEER, G. R. (1926 a) : Studies on the vertebrate head part II. The orbito-temporal region of the skull. Quart. Journ. Micr. Sci., V. 70, pp. 263-368.
- — — (1926 b) : On the development of the skull in *Torpedo*. Quart. Journ. Micr. Sci., V. 70, pp. 669-678.
- — — (1931) : The development of the skull of *Scyllium canicula*. Quart. Journ. Micr. Sci., V. 74, pp. 591-645.
- — — (1932) : On the skeleton of the Hyoid Arch in Rays and Skates. Quart. Journ. Micr. Sci., V. 75, pp. 307-320.

- DE BEER, G. R. (1937) : The development of the vertebrate skull. Clarendon press, Oxford.
- DOHRN, A. (1884) : Studien zur Urgeschichte des Wirbelthierkörpers. IV. Die Entwicklung und Differenzierung der Kiemenbogen der Selachier. Mitt. Zool. Stat. Neapel. V.
- DORIS, R. (1925) : The Comparative Morphology of the caecal gland (Rectal gland) of selachian fishes, with some reference to the morphology, physiology of the similar intestinal appendages throughout Ichthyopsida and Sauropsida. Proc. Zoo. Soc. London, pp. 101-188.
- DUMERIL, A. M. (1806) : Zoologie analytique. Paris.
- EDGEWORTH, F. H. (1925) : On the autostylism of Dipnoi and Amphibia. Journ. Anat., V. 59, pp. 225-264.
- — — (1931) : On the development of the hyoid bar and rays in Plagiostomi. Journ. Anat., V. 66.
- EL-TOUBI, M. R. (1947) : The development of the spiracular cartilage of the spiny dogfish, *Acanthias vulgaris* (*Squalus acanthias*). Biol. Bull., V. 93, pp. 287-295.
- — — (1949) : The development of the chondrocranium of the spiny dogfish, *Acanthias vulgaris* (*Squalus acanthias*), Part I. Neurocranium, mandibular and hyoid arches. Journ. Morph., V. 84, pp. 227-279.
- — — (1952) : The development of the chondrocranium of the spiny dogfish, *Acanthias vulgaris* (*Squalus acanthias*) Part II. The branchial skeleton and extravisceral cartilages. Journ. Morph., V., 90, pp. 33-64.
- EL-TOUBI, M. R. AND HAMDY, A. R. : The head skeleton of *Rhinobatus halavi*, *Rhynchobatus djiddensis* and *Trygon kühlii*. Publ. Mar. Biol. Sta. Ghardaqa, No. 10, pp. 3-39.
- FOXON, G. H. (1950) : A description of the coronary arteries in Dipnoian fishes and some remarks on their importance from the evolutionary stand-point. Jour. Anat. 84 : 121-31.
- FÜRBRINGER, K. (1903) : Beiträge zur kenntnis des visceralskelets der Selachier. Morph. Jahrb., V. 31, pp. 360-445.
- FOOTE, E. (1897) : The extrabranchial cartilages of the Elasmobranchs. Anat. Anz., V. 13.
- GARMAN, S. (1885) : *Chlamydoselachus anguineus*, a living species of Cladodont shark. Bull. Mus. Comp. Zool., V. 12, pp. 1-36.
- GAUPP, E. (1906) : Die Entwicklung des Kopfskeletts. Handb. vergl. exp. Entw. Wirbelt. V. 3, pp. 305-308.
- GEGENBAUER, C. (1872) : Untersuchungen zur vergleichenden Anatomie der Wirbelthiere. III das Kopfskelet der Selachier. Leipzig.
- GOHAR, H. A. F. and BAYOUMI, A. R. (1959) : On the Anatomy of *Manta ehrenbergi*, with Notes on *Mobula kühlii*. Publ. Mar. Sta., Ghardaqa, Red Sea., No. 10. pp. 191-238.
- GOHAR, H. A. F. and MAZHAR, F. M. (1964) : Elasmobranchs of North-Western Red Sea. Publ. Mar. Biol. Sta., Al-Ghardaqa, Red Sea, No. 13 pp. 3-144.
- GOODEY, T. (1910) : A contribution to the skeletal anatomy of the frilled shark, *Chlamydoselachus anguineus* Gar. Proc. Zool. Soc. London.
- GOODRICH, E. S. (1909) : A treatise on Zoology. Vertebrata Craniata. Cyclostomes and Fishes. London.
- — — (1918) : On the development of the segments of the head in *Scyllium*. Quart. Journ. Micr. Sci., V. 63, pp. 1-30.
- — — (1930) : Studies on the structure and development of Vertebrates. London.
- Gudger, E. W. (1953) : Maxillary Breathing Valves in the sharks *Chlamydoselachus* and *Cetorhinus* with notes on Breathing valves in 13 Marine Teleosts. J. Morph. 57 : 91-4.
- — — (1940) : The Breeding Habits, Reproductive Organs and external embryonic development of *Chlamydoselachus* based on notes and drawings by Bashford Dean. Bashford Dean Memorial Vol. Archiac Fishes, Part II, Article VII, pp. 521-646.
- — — (1946) : Oral Breathing Valves in Fishes. bid. 79 : 263-85.

- HAMDY, A. R. (1952) : Hyoid arch of *Rhinobatidae*. *Nature*, V. 170. p. 166.
- — — (1955 a) : The development of the spiracular cartilage of *Rhinobatus halavi*. *Proc. Egypt. Acad. Sci.*, V. 11, pp. 74-78.
- — — (1955 b) : The development of the extravisceral cartilages of *Rhinobatus halavi*. *Proc. Egypt. Acad. Sci.*, V. 11, pp. 79-83.
- — — (1956) : The development of the hyoid arch in *Rhinobatus halavi*. *Proc. Egypt. Acad. Sci.*, V. 12, pp. 58-71.
- HARRISON, B. M. (1931) : Developmental stages of the chondrocranium in some selachians. *Journ. Morph.*, V. 52.
- HASSE, C. (1879) : Das Natürliche System der Elasmobranchier. *Fischer. Jena*. 1879.
- HASWELL, W. A. (1884) : Studies on the Elasmobranch skeleton. *Proc. Linn. Soc. N. S. Wales*, V. 9.
- HOLMGREN, N. and STENSIO, E. (1936) : Kraniaum und Visceralskelett der Akranier, Cylostomen und Fische. *Bolk Handb. verg. Anat. Berlin*, V. 4, pp. 233-500.
- HOSKINS, E. R. (1917) : On the Development of the Digitiform Gland and the Posterior valvular segment of the intestine in *Squalus acanthias*. *J. Morph.*, 28, 329.
- HOWES, G. B. (1890 a) : On the Visceral anatomy of the Australian torpedo (*Hypnos subnigrum*). *Proc. Zool. Soc.*, London, 669.
- — — (1890b) : On the intestinal canal of the Ichthyopsida with special reference to its arterial supply and the appendix digitiformis. *J. Linn. Soc. Lond. (Zool.* 23, 381).
- HUBER, OSCAR (1901) : Die Kopulationsglieder der Selachier. *Zeitschr. Wiss. Zool.*, LXX.
- HUXLEY, T. H. (1876) : Contributions to morphology. Ichthyopsida. No. 1. On *Ceratodus forsteri*, with observations on the classification of fishes. *Proc. Zool. Soc.*, London, pp. 24-59.
- ISELSTOGER, H. (1937) : Das Neurocranium von *Rhina squatina* und einige Bemerkungen über ihre systematische Stellung. *Zool. Jahrb. Abt. Anat. W. Ontog.* V. 62.
- JAEKEL, O. (1895) : Über die Organisation der Pleuracanthiden. *Sitz. Ges. Nat. Fr.*, Berlin.
- KRIVETSKI, A. (1917) : Sur la morphologie des éléments de l'arc hyoïde chez les Sélaciens. *Rev. Zool. Russe*, V. 2.
- MARPLES, B. J. (1935-36) : The blood vascular System of the Elasmobranch Fish *squatina* (Linné). *Transactions Royal Society of Edinburgh*, Vol. LVIII-Part III, No. 28.
- MATTHEWS, L. H. (1950) : Reproduction in the Basking Shark *Cetorhinus maximus* (Gunner). *Phil. Trans. Roy. Soc. Lond. Series B*, No. 612, 234 : 247-316.
- MATTHEWS, L. H. and PARKER, H. W. (1950) : Notes on the Anatomy and Biology of the Basking Shark (*Cetorhinus maximus*). *Proc. Zool. Soc. Lond.* 120 (3) : 535-76.
- MAZZA, F. (1891 a) : Sul Tubo Gastero-enterico della *Cephaloptera giornae*. *Ann. Mus. Civ. Storia Nat. Genova*, 10 : pp. 519-36.
- — — (1891 b) : Appunti Anatomici sul Cuore della *Cephaloptera giornae*. *ibid.* 10 : pp. 998-1009.
- MELOUK, M. A. (1953) : On the early development and innervation of the mandibular line in the elasmobranchii. *Bull. Fac. Sci. No. 32*, pp. 71-72.
- — — (1957) : On the Development of *Carcharinus melanopterus* (Q. and G.) *Publ. Mar. Biol. Sta., Al-Ghardaqa, Red Sea No.*, 9, pp. 229-252.
- MÜLLER, J. (1837) : Ueber die Genesis der Wirbel beiden Fischen. *Mitt. Ges. Naturf. Freunde, Berlin*.
- OCAMPO, R. R., HALASTEAD, B. W. and MODGLIN, F. R. (1953) : The Microscopic Anatomy of the caudal Appendage of the Spotted Eagleray, *Aetobatus narinari* (Euphrasen), with special reference to the venom apparatus. *Anatomical Record*, vol. 115, No. 1, January

- OWEN, R. (1866) : Anatomy of Vertebrates. I. London.
- — — (1840-45) : Odontography. 2 Vols. London : Hippolyte Bailliere.
- PARKER, T. J. (1887) : Notes on *Carcharodon rondeletti*. *Proc. Zool. Soc.*, London.
- PARKER, W. K. (1879 a) : On the structure and development of the skull in sharks and skates. *Trans. Zool. Soc.*, V. 10, pp. 189-234.
- — — (1879 b) : On the intestinal spiral valve of the genus *Raja*. *Trans. Zool. Soc. London*, XI.
- PARSONS, C. W. (1930) : The conus arteriosus in Fishes. *Quart. J. Micro. Sci.*, 73, pp. 145-176.
- POLLARD, H. B. (1895) : The oral cirri of siluroids and the origin of the head in vertebrates. *Zool. Jahrb. Abt. Anat.*, V, 8, pp. 379-424.
- RATHKE, H. (1832) : Untersuchungen über den Kiemenapparat und das Zungenbein der Wirbelthiere. *Riga und Dorpat*.
- RAND, H. W. (1907) : The Functions of the Spiracle of the Skate. *Amer. Nat.*, Vol. 41, pp. 287-302.
- REDEKE, H. C. (1900) : Die Sogenannte Bursa Entiana der Selachier. *Anat. Anz.*, 17, pp. 146-59.
- ROMER, A. S. (1950) : The Vertebrate Body. Philadelphia and London.
- SEWERTZOFF, A. N. (1923) : Die Morphologie des Visceralapparates der Elasmobranchier. *Anat. Anz.*, V. 56, pp. 389-410.
- SCAMMON, B. (1911) : Normal plates of the development of *Squalus acanthias*. *Keibels Normen. tafeln* 12.
- SEDGWICK, A. (1892) : Notes on Elasmobranch Development. *Quart. J. Micro. Sci.*, 33, pp. 559-586.
- SMITH, B. G. (1937) : The Anatomy of the Frilled Shark *Chlamydoselachus anguineus*. The Bashford Dean Memorial Volume, Article 6, Fishes. Part II. Article 6, *Amer. Mus. Nat. Hist.*, N. Y.
- THILLAYAMPALAM, E. M. (1928) : *Scoliodon*, the common shark of the Indian seas. *Indian Zool. Memoirs*, II, Univ. of Lucknow.
- VAN WIJHE, J. W. (1902) : A new method for demonstrating cartilaginous microskeletons. *Proc. Kon. Akad. van Wetensch. te Amsterdam*, V. 5, pp. 47-51.
- WATSON, D. M. S. (1937) : The Acanthodian fishes. *Philos. Trans. Roy. Soc. London. Series B*, V. 228, pp. 49-146.
- WELLS, G. A. (1917) : The skull of *Acanthias vulgaris*. *Journ. Morph.*, V. 28, pp. 417-443.
- WHITE, E. G. (1936 a) : A classification and Phylogeny of the Elasmobranch Fishes. *Am. Mus. Nov.*, 837, pp. 1-16.
- — — (1936 b) : The Heart valves of the Elasmobranch Fishes. *Ibid.* 838, pp. 1-9.
- WHITE, E. G. (1937) : Interrelations of the Elasmobranchs with a key to the order Galea. *Bull. Amer. Mus. Nat. Hist.*, V. 74.
- WHITE, P. J. (1892) : The skull and visceral skeleton of the Greenland shark, *Læmargus microcephalus*. *Trans. Roy. Soc. Edinburgh*, V. 37, pp. 287-306.



## VIII.—EXPLANATION OF THE PLATS

## PLATE I

- (1) *Galeocерdo cuvier*, anterior view of an opened mouth showing bucco-pharyngeal cavity. (2) *Galeocерdo cuvier*, hind part of oesophagus and cardiac stomach opened lengthwise ventrally to show internal lining. (3) *Carcharhinus melanopterus*, abdominal cavity opened lengthwise to show alimentary tract *in situ* (lobes of liver stretched to the sides). (4) *Nebrius concolor*, oesophagus and proximal portion of stomach opened lengthwise ventrally to show internal lining.

## PLATE II

- (1) *Nebrius concolor*, posterior portion of pyloric stomach and proximal part of intestine, opened lengthwise from ventral side. (2) *Taeniura lymma*, roof of bucco-pharyngeal cavity. (3) *Taeniura lymma*, floor of bucco-pharyngeal cavity. (4) *Aëtobatus narinari*, ventral view of alimentary canal *in situ* (liver removed).

## PLATE III

- (1) *Aëtobatus narinari*, oesophagus and proximal portion of stomach opened lengthwise ventrally to show internal lining. (2) *Aëtobatus narinari*, posterior portion of pyloric stomach and proximal part of intestine opened lengthwise from ventral side. (3) *Mobula kühlii*, oesophagus and proximal portion of stomach opened lengthwise ventrally to show internal lining. (4) *Mobula kühlii*, pyloric stomach and proximal part of intestine (duodenum) opened lengthwise from left latero-ventral side.

## PLATE IV

- (1) *Rhynchobatus djiddensis*, inner side of jaws showing buccal valves and teeth. (2) *Rhynchobatus djiddensis*, part of oesophagus, cardiac stomach and proximal portion of pyloric stomach, opened lengthwise ventrally to show internal lining. (3) *Rhynchobatus djiddensis*, posterior portion of pyloric stomach and intestine opened lengthwise from ventral side. (4) *Rhinobatos halavi*, part of oesophagus and stomach opened lengthwise ventrally to show internal lining. (5) *Rhinobatos halavi*, posterior portion of pyloric stomach and intestine opened longwise from ventral side.

## PLATE V

- (1) *Galeocерdo cuvier*, conus arteriosus and ventricle opened from ventro-lateral side, walls stretched to show three rows of valves of conus arteriosus (dorsal row of valves is in middle, and ventro-lateral two rows are at sides) and internal structure of ventricle. (2) *Nebrius concolor*, conus arteriosus and ventricle opened from ventro-lateral side. (3) *Aëtobatus narinari*, dorsal view of heart with free margins of auricle cut opened to show sinu-auricular opening with its valves, auriculo-ventricular opening and 4-cuspid valve. (4) *Aëtobatus narinari*, conus arteriosus and ventricle opened from ventro-lateral side.

## PLATE VI

- (1) *Rhynchobatus djiddensis*, conus arteriosus and ventricle, opened from ventro-lateral side. (2) *Rhinobatos halavi*, conus arteriosus and ventricle opened from ventro-lateral side.

## PLATE VII

- (1) *Nebrius concolor*, part of oviduct and shell-gland opened longwise ventrally to show internal structures. (2) *Nebrius concolor*, part of internal wall of uterus. (3) *Mustelus canis*, a female with 10 embryos in the uteri. (4) *Rhinobatos halavi*, part from internal wall of uterus of pregnant female. (5) *Rhynchobatus djiddensis*, part from internal wall of uterus of pregnant female.

## PLATE VIII

- (1) *Galeocерdo cuvier*, Dorsal view of brain and cranial nerves (specimen 305 cm. long). (2) *Galeocерdo cuvier*, lateral view of brain and cranial nerves. (3) *Galeocерdo cuvier*, ventral view of brain and cranial nerves. (4) *Nebrius concolor*, dorsal view of brain *in situ*.

## PLATE IX

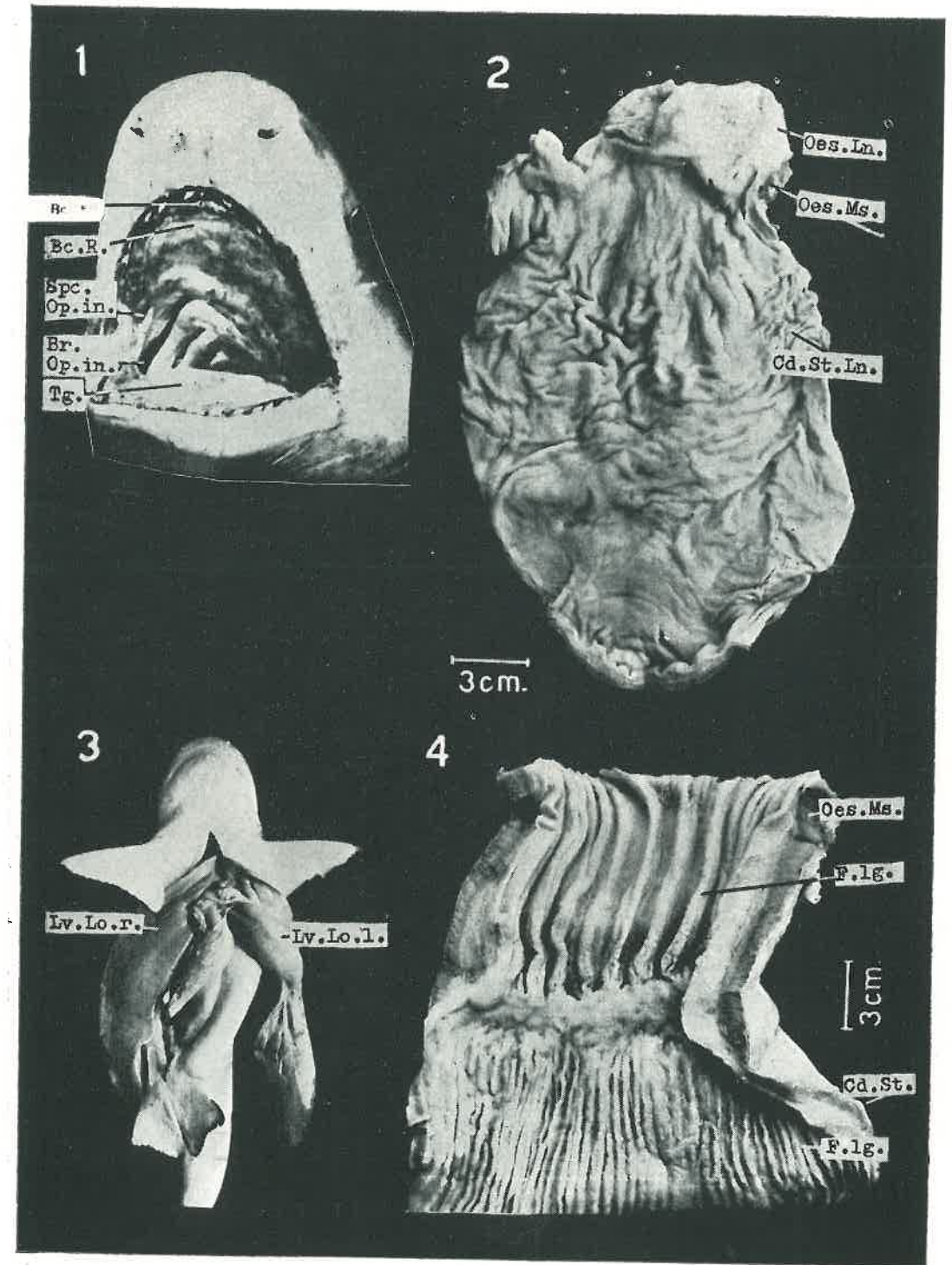
- (1) *Nebrius concolor*, dorsal view of brain and cranial nerves (specimen 215 cm. long). (2) *Nebrius concolor*, ventral view of brain and cranial nerves (VI nerve cut) (3) *Nebrius concolor*, lateral view of brain and cranial nerves. (4) *Aëtobatus narinari*, dorsal view of brain *in situ*. (5) *Taeniura lymma*, dorsal view of brain *in situ*.

## PLATE X

- (1) *Aëtobatus narinari*, dorsal view of brain and cranial nerves (specimen 250 cm. long, IV nerve cut). (2) *Aëtobatus narinari*, ventral view of brain and cranial nerves. (3) *Aëtobatus narinari*, lateral view of brain and cranial nerves. (4) *Rhinobatos halavi*, dorsal view of brain and cranial nerves (specimen 171 cm. long).

## PLATE XI

- (1) *Rhinobatos halavi*, ventral view of brain and cranial nerves. (2) *Rhinobatos halavi*, lateral view of brain and cranial nerves. (3) *Rhynchobatus djiddensis*, dorsal view of brain *in situ*. (4) *Rhynchobatus djiddensis*, dorsal view of brain and cranial nerves (specimen 280 cm. long).



Figs. 1 and 2 : *Galeocerdo cuvier* ;  
Fig. 4 : *Nebrius concolor*.

Fig. 3 : *Carcharhinus melanopterus* ;



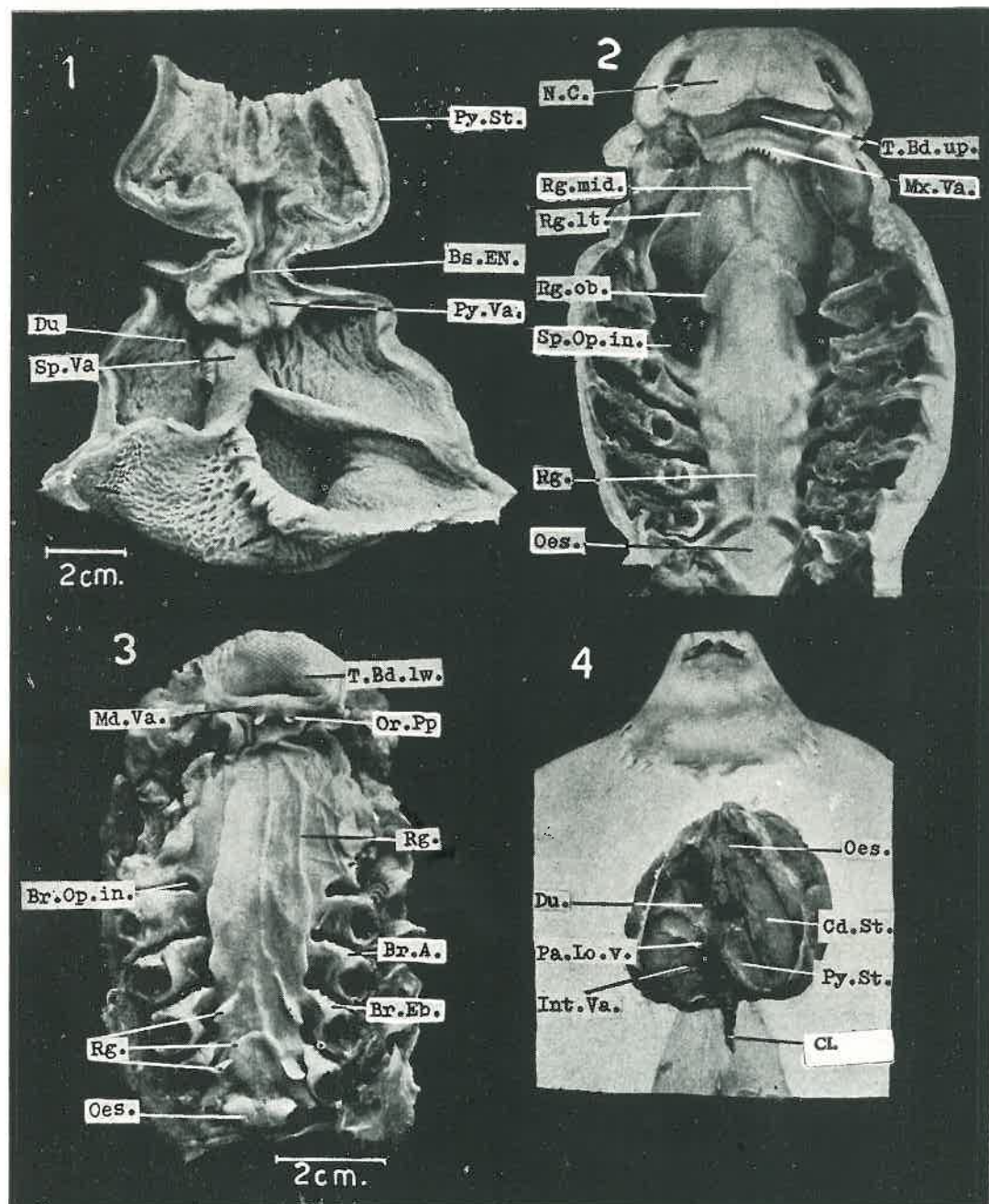
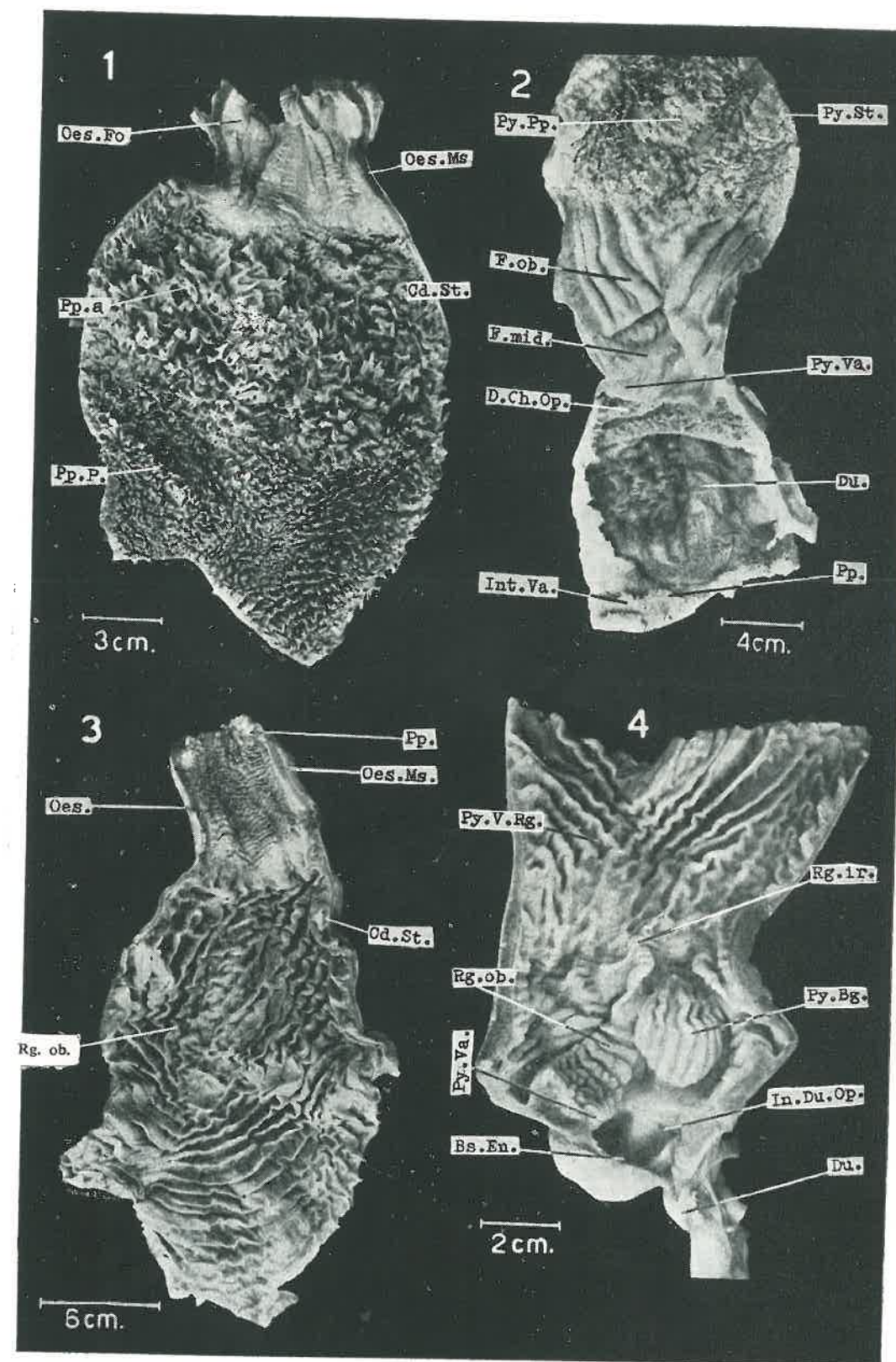


Fig. 1 : *Nebrius concolor* ;  
Fig. 4 : *Aetobatus narinari*

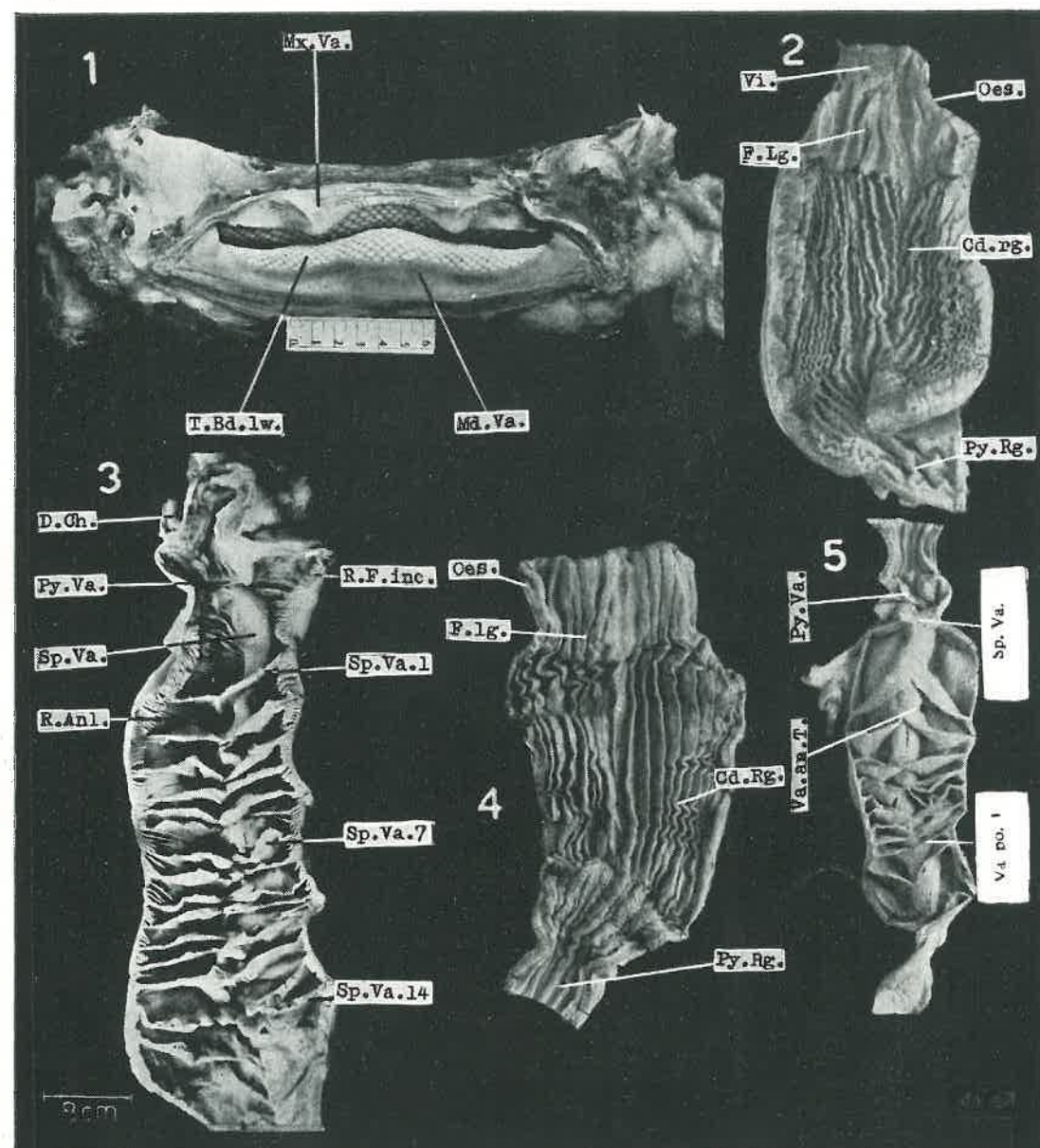
Figs. 2 and 3 : *Taeniura lymna* ;



Figs. 1 and 2 : *Aetobatus narinari* ;

Figs. 3 and 4 : *Mobula kuhlii*.





Figs. 1—3 : *Rhynchobatus djiddensis* ;

Figs. 4 & 5 : *Rhinobatos halavi*.

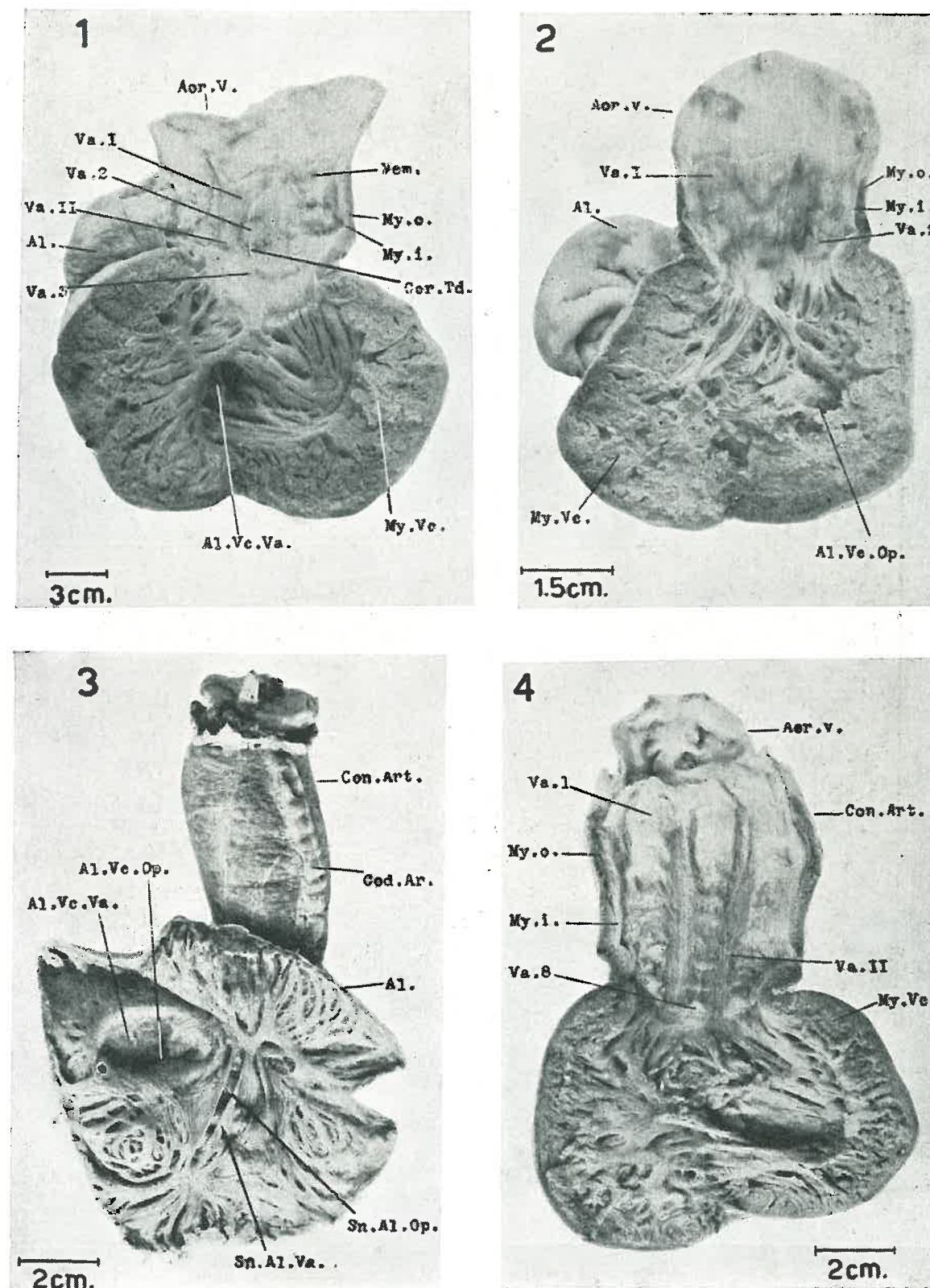


Fig. 1 : *Galeocerdo cuvier* ;

Fig. 2 : *Nebruis concolor* ;

Figs. 3 aad 4 : *Aetobatus narinari*.



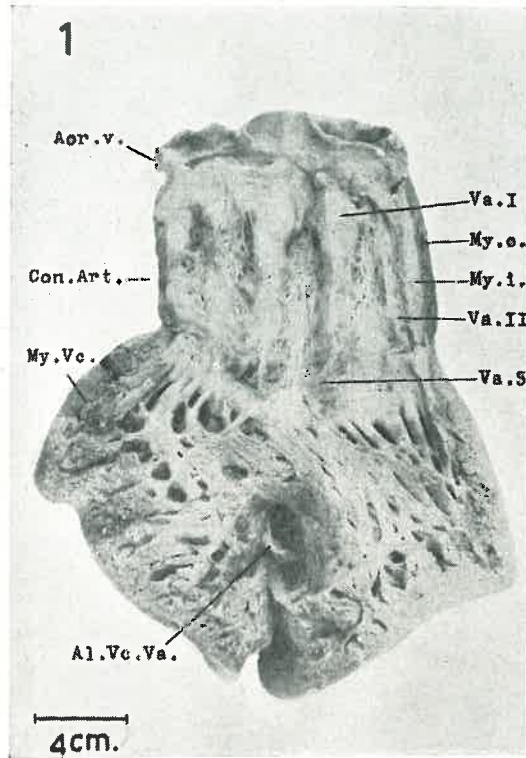


Fig. 1 : *Rhynchobatus djiddensis* ;

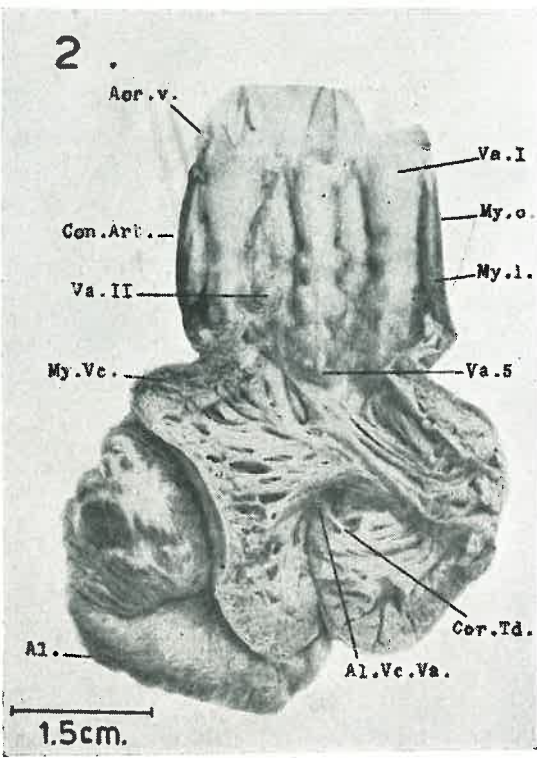
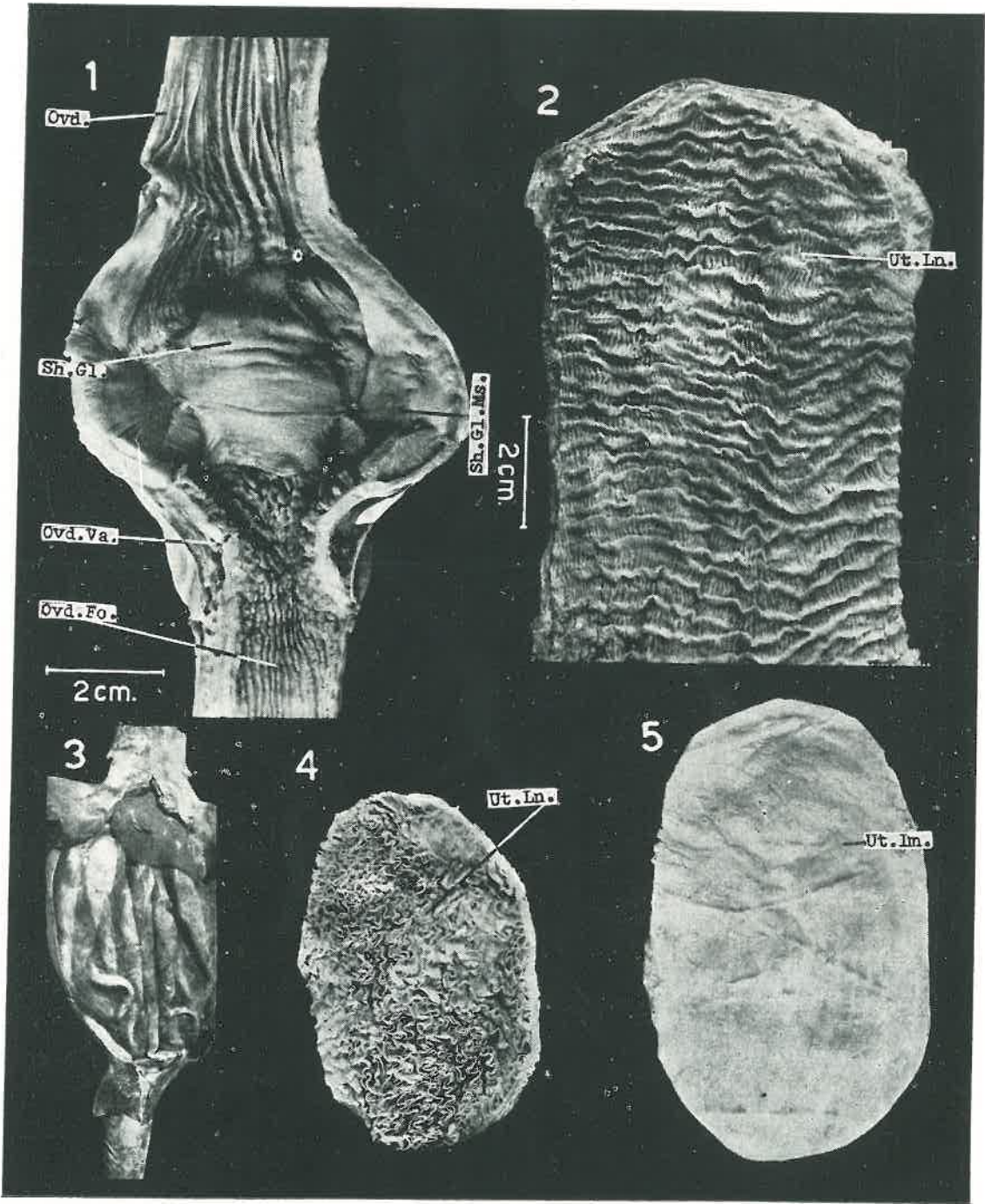


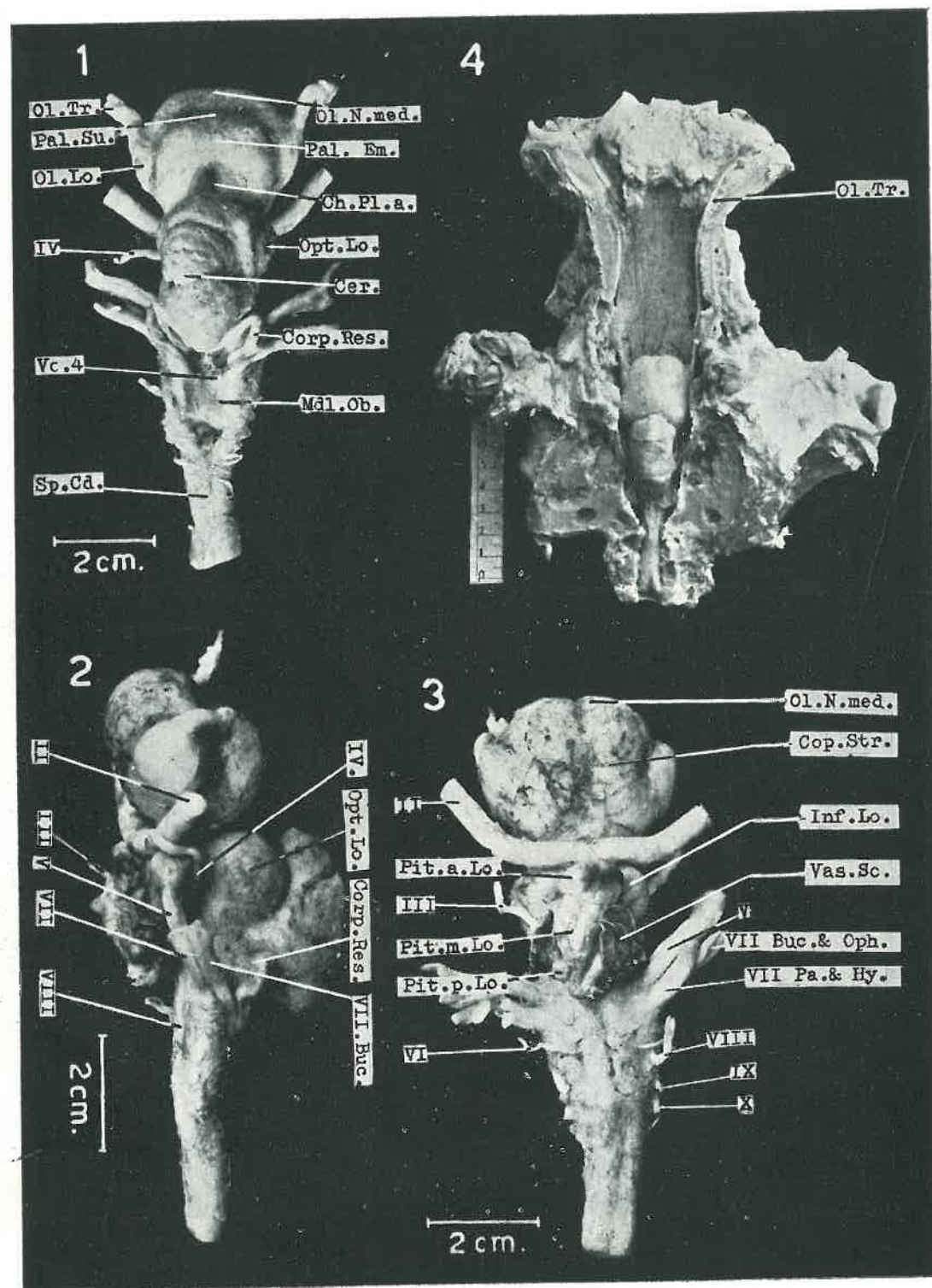
Fig. 2 : *Rhinobatos halavi*.



Figs. 1 and 2 : *Nebrius concolor* ;  
Fig. 4 : *Rhinobatos halavi* ;

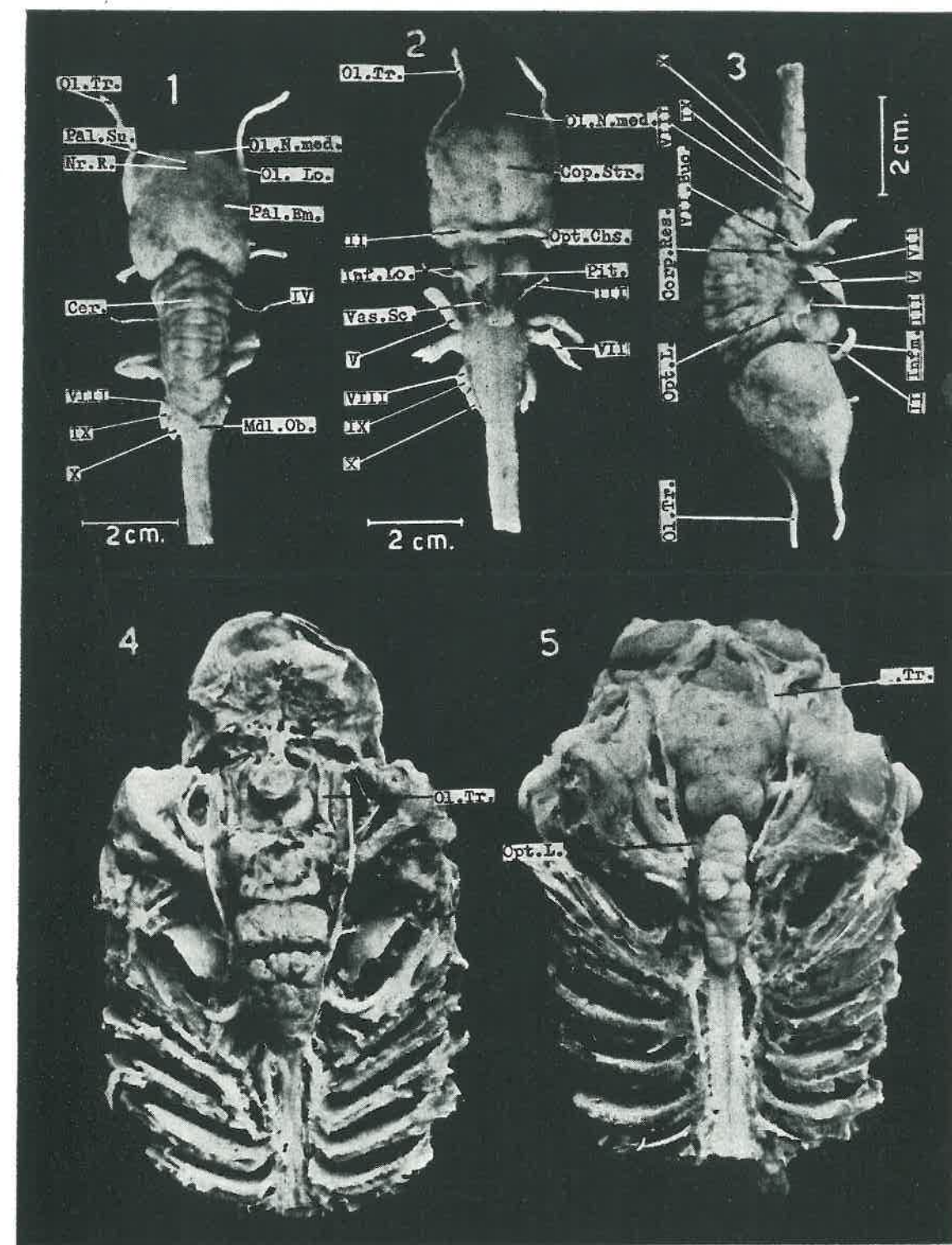
Fig. 3 : *Mustelus canis* ;  
Fig. 5 : *Rhynchobatus djiddensis*.





Figs. 1-3 : *Galeocerdo cuvier* ;

Fig. 4 : *Nebrius concolor*.

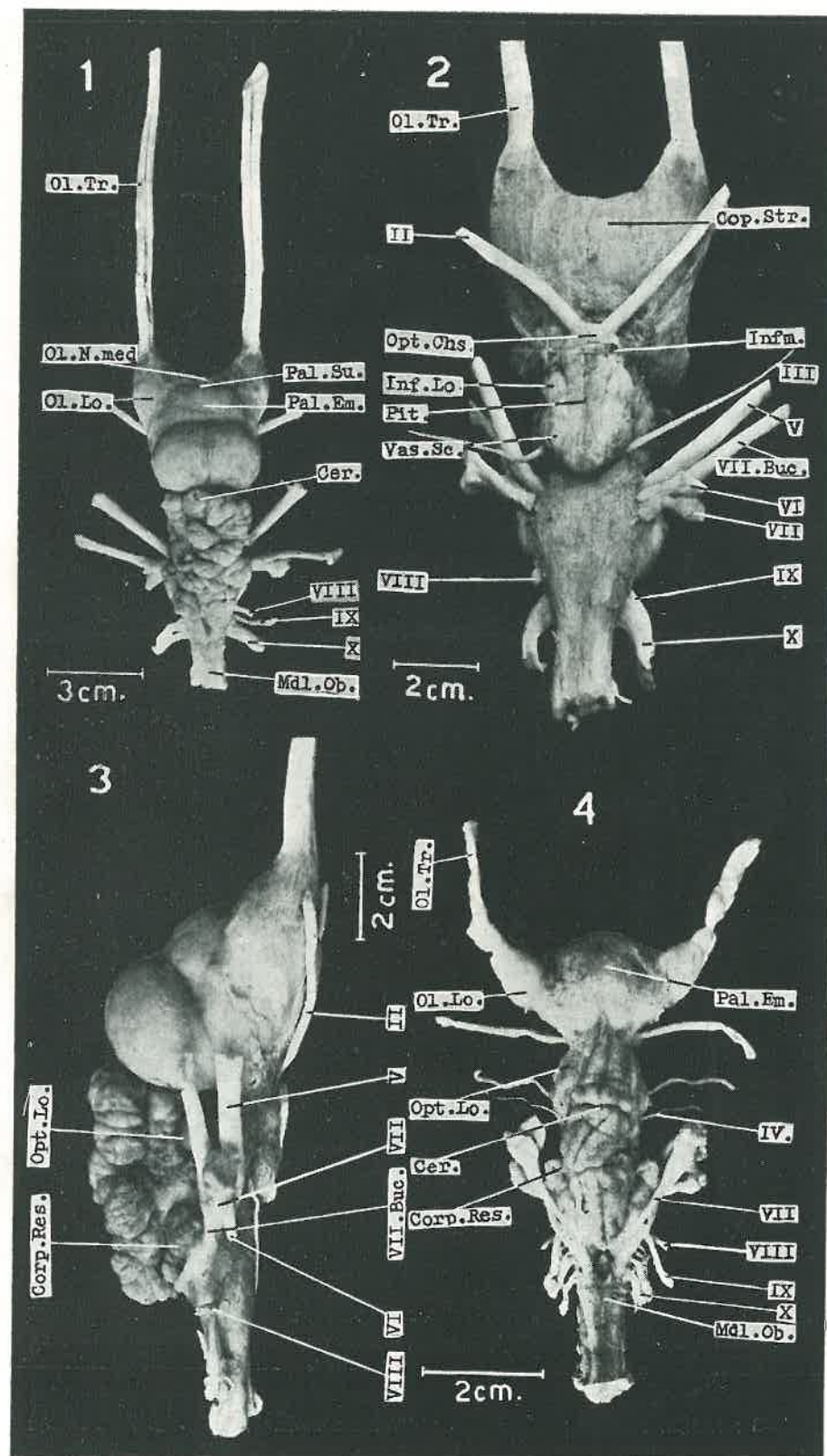


Figs. 1-3 : *Nebrius concolor* ;

Fig. 4 : *Aëtobatus narinari* ;

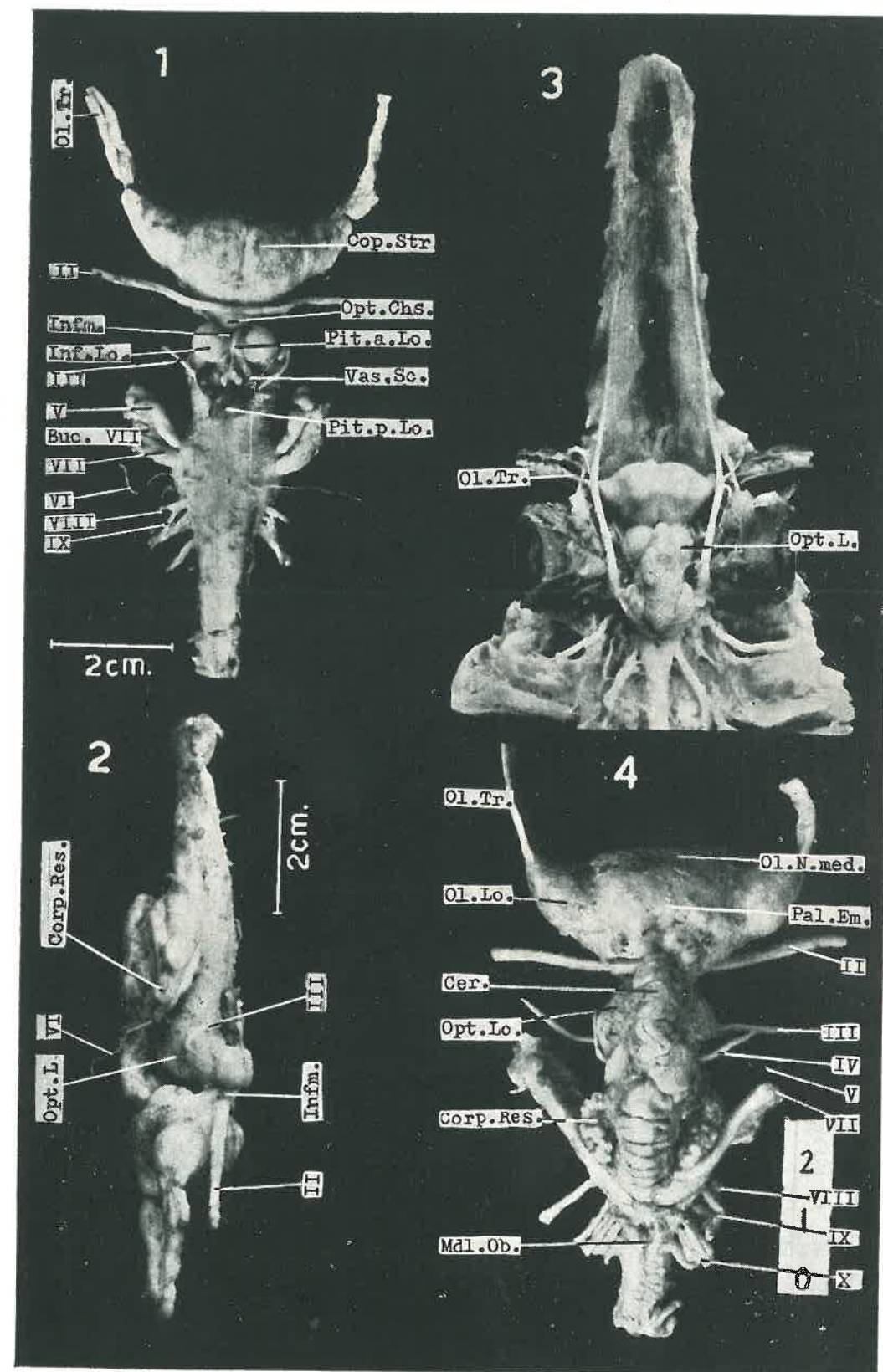
Fig. 5 : *Taeniura lymma*.





Figs. 1—3 : *Aetobatus narinari* ;

Fig. 4 : *Rhinobatos halavi*.



Figs. 1 & 2 : *Rhinobatos halavi* ;

Figs. 2 & 4 : *Rhynchobatus djiddensis*.