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CONTENTS

	PAGE
GOHAR, H. A. F.: The Red Sea Dugong	3
BATRAWI, A. : The Structure of the Dugong Kidney	51
GOHAR, H. A. F. and ABUL-ELA, I. A. : The Development of *Berthellina citrina* (Mollusca)	69
GOHAR, H. A. F. and AL-KHOLY, A. A.: The Larval Stages of Three Stomatopod Crustacea	85
GOHAR, H. A. F. and ABUL-ELA, I. A.: On a New Nudibranch (*Phyllodesmium xeniae*)	131
GOHAR, H. A. F. and AL-KHOLY, A. A.: The Larvae of Some Brachyuran Crustacea	145
GOHAR, H. A. F. and AL-KHOLY, A. A.: The Larvae of Decapod Crustacea	177
GOHAR, H. A. F. and ABUL-ELA, I. A.: The Development of Three Chromodorids	203
MELOUK, M. A.: On the Development of *Carcharinus melanopterus* ...	229

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A Special Number on the Occasion of

THE SILVER JUBILEE

OF

THE MARINE BIOLOGICAL STATION,

AL-GHARDAQA

1931-1956

CORRIGENDA

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INTRODUCTION

Although the Red Sea is usually included within the range of distribution for the dugong (Sclater, 1899, p. 351, Weber 1928, II p. 494, etc.), yet there has been only a single authenticated record of its occurrence in this area. That record was made by Rüppell in the year 1833 (pp. 97-114), when he gave a general description of a female specimen which he had obtained.

Rüppell, at that time, was certainly unaware of Ehrenberg's Symbolae Physicae (1928) which had appeared five years before, and where Ehrenberg had given a scrappy description of some bones of the Red Sea dugong. He established the species *Halicore hemprichii* on the basis of a skull found at Barkan Island in the Red Sea; and on the basis of a few teeth from Hanakel Island Ehrenberg established another species which he called *H, lottum.*

Rüppell's account appears to be one of the earliest we have on the dissection of the dugong, and, considering the hard conditions under which Rüppell worked, it is reasonably accurate and forms a good foundation for our knowledge of the gross anatomy and osteology of the animal. Nevertheless, Rüppell's account has remained unnoticed for long and, has been overlooked by most later authors. Dugongs are fairly common in the Indo-Malayan Islands and along the north-eastern coast of Australia, as well as the coast of Ceylon; less common on the coast of East africa and round Madagascar. In the Red Sea, however, they have become so rare that in the century or more that followed Ruppell's work, no other record was made. In fact, dugongs were believed to have become extinct in this area; a fact which would have been expected, in view of the defenseless nature of those creatures and the relentless pursuit by fishermen who would seek them for their flesh, oil, hide and tusks.

In January 1942, however, while searching beach sand for miscellaneous specimens, I came across some mammalian bones including jaw bones and a broken skull. By the aid of the latter the bones were identified as dugong bones. They were burried in the sand and appeared to belong to an animal, which must have died only a few years before. This find aroused my interest and gave the impetus for a long and continuous search after this interesting and rare animal. I had, then, been working on the Red Sea for over ten years, and had been engaged in making a representative collection, or at least records, of the members of the fauna of that sea, but never had I observed or heard of the occurrence in it of such an animal. Long enquiry amongst elderly fishermen revealed that some of them knew it by the name of « **gueld** » meaning « skin or leather», probably pointing to the usefulness of its skin, or to its resemblance to

a large skin turgid-full of water, such as is used in that part of the desert for carrying water, and made of goat or cattle skin.

In the northern part of the Red Sea, it is known as « naqat al-bahr » meaning the « sea-camel ». Those few fishermen, who knew of it, highly esteemed its flesh and fat.

Harpooning as a means for obtaining specimens — as normally practiced in the Indo-Australian Archipelago — was naturally futile, owing to the scarcity of these animals. Resort had, therefore, to be taken to nets. Ordinary nets mutilate the animals delicate skin, as strong ropes tend to produce large cuts, and special nets had, therefore, to be made for this particular purpose, using ropes of loosely twisted fine linnen threads. The nets made were 50-70 meters long by 5 meters broad, and had four meshes for the square metre. Several such net-units are used together. The upper edge of the net is floated by corks, the opposite edge sinking by its own weight. One end of the lower edge of the net is fastened hard to the bottom by a boat-anchor, the other end is held in place simply by a weight, generally a stone. The dugong being strictly herbivorous, the nets are placed in localities where sea-grasses are abundant, particularly where a narrow passage occurs between coral reefs or between a reef and the shore. The nets are set in such a manner as to close these passages and block the way in the face of the larger animals roaming about in those localities for food.

Several such places between Al-Ghardaqa and Ras Giemsa in the north (70 kms), were tried. In less than two weeks we had our reward of a half grown male specimen, 198 cms. long from the tip of the muzzle to the end of the tail (middle of the tail fluke). This was caught at Ras el-Esh, 55 kms. north of our Station in the night of November 7th 1942. This finding was recorded in the Cairo daily paper « Al Ahram » on Dec. 15th 1942, p. 3, where a photograph of that specimen was given, also in the Station annual report for 1942-43 (Gohar 1942 and 1944).

This find created interest and stimulated us to launch a long and continued search programme, in order to obtain more specimens. Nevertheless, it was not until after the lapse of 27 months of continued unslakening effort that we succeeded, and this time our recompense consisted of two mature females, caught in February 1945 at a locality only three kilometres north of our Station.

In all, about 15 specimens were procured in the thirteen years that followed. They were mostly caught single but on two occasions a pair of a male and a female were obtained at each time, and on a third occasion two females were caught together.

Besides the account by Rüppell in 1833 referred to above, Owen - in 1838 - gave a description of the viscera of the Malayan dugong, and

recently Osman Hill (1945, p. 153) published a somewhat comprehensive account of the general dissection of two dugongs from Ceylon. Apart from that there are a few notes giving fragmentary information on dugongs from various parts of the Indian Ocean, but especially dealing with the skeleton.

It was hoped to give a full account of the anatomy and histology of the Red Sea dugong and to throw special light on the many interesting points in this respect. It has been very unfortunate, however, that it so happened that the catch of dugongs often occurred at times when I had other pressing duties and no other person was available to undertake the study. Thus, I have to be contented, for the present, to give in the present communication a description of the general features of the Red Sea dugong, laying some stress on the specially debatable points. Organs have also been preserved for study in due course and papers are in preparation dealing with the physiological anatomy and histology of the alimentary tract as well as of the endocrine and other glands. Professor A. Batrawy gives in the next paper in the present number of our «Publications» an interesting and thorough account on the anatomy of the kidneys. In 1949 (p. 1) Professor I. S. Hilmy described four new paramphistome parasites which I had found in the caecum of some dugongs. Dr. Aziza Hanna of the Dept. of Anatomy, Faculty of Medicine, Cairo University, will give a general description of the stomach to appear in the Proc. Zool. Soc. Egypt.

GENERAL FEATURES

Perhaps the first thing that strikes the attention, about the dugong, is the great turgidity of the body; the skin being intensely stretched, smooth, and shows no wrinkles at all, except at a few places, where a certain amount of mobility is required.

The shape of the animal — a stiff body with a relatively very large waist-line, almost completely circular in cross section and provided with proportionately small and apparently inefficient flippers — suggests great slothfulness. The relatively large tail-flukes, meet the demands of frequent rise to the surface for respiration.

Deprived of all kinds of offensive weapons, dugongs — usually living in small families — often retire to well-sheltered bays and lagoons of shallow water, where their food of sea-grasses is abundant and where they may live in relative security from the assaults of larger and stronger predaceous animals. They are also very shy creatures and always keep away from places where they may be disturbed by vessels and fishermen.

Hence, they are hardly seen; at all events at close distances. Many bays and lagoons in the Red Sea possess large beds particularly rich in the proper sea-grasses that form the food of the dugong, besides being in other respects obviously very suitable for dugong visits. A number of these areas, however, are scarcely frequented by these animals and it is evident that the main cause for their absence lies in the disturbance imposed upon them by man, as well as the relentless fishing that must have taken a great toll of them in the past, reducing them to the very few families now existing. Although in those shallow bays and lagoons, dugongs are sheltered from the action of heavy surf of open water, they are here subjected to another kind of water movements; that produced by wave currents and tidal streams. To these, the dugong is remarkably adapted. The streamline of the body - which is necessary to insure fastness of movement when escape is imperative - helps the spinning of such a spindle-shaped animal. Stabilization is, however, brought about, not only by the large tail-flukes and the flippers, but also by the arrangement of the internal viscera. This is achieved by the light greatly elongated lungs lying at the dorsal side of the body and extending along its entire length to almost the end of the trunk, while the very long capacious bowels, which are always heavily stuffed with sea-grasses, are packed in the ventral side of the coelum. So that when the belly is opened the intestines are seen to fill the abdominal cavity concealing every thing else. They are coiled in hoof-like layers accross the abdomen and are of considerable length and width (Pl. I fig. 2).

In colour dugongs vary but little from one animal to another and, in general, it seems that older individuals are somewhat darker than the younger. The dorsal side of the body is also darker than the ventral. Thus the general colour of the back is dirty grey with a faint brownish tinge, getting lighter on the sides to merge into the belly where the colour is white with a slight light greenish yellow hue. The ventral surface of the muzzle is more greenish, but this may be due to colour imparted by the juices of the sea-grasses constituting the food of the animal. The body has assumed a torpido-like shape as is the case with many aquatic vertebrates. It is almost perfectly circular in transverse section, although it has been often described as somewhat compressed dorso-ventrally, but this is probably mainly a result of the pressure of its own weight when taken out of water. It is characterized by a proportionately small head which curves slightly, anteriorly to end in a broad, abruptly flattened, ventrally directed snout, suggesting a truncated proboscis. This subserves the function of gathering the food sea-grasses, besides a sensory function. These functions are clearly reflected in the general morphology of the organ (Text fig. 1). It is, thus, endowed with a certain power

of muscular activity. For this purpose the skin, in this region, is provided with three main sulci,; a median sulcus and two lateral ones, the latter running roughly parallel, and a little distance median, to the edge of the disc. A few smaller sulci also occur irregularly scattered on the surface of the snout. Besides, the snout widens out a little — but conspicuously and almost abruptly — towards the flattened surface, forming a sort of flap-like border, surrounding that surface and separated from the anterior and lateral sides of the snout by a shallow sulcus extending all round the disc except for the oral side. This sturcture also helps a certain amount of folding of the organ.

The surface of the disc is crowded with large pores, from each of which protrudes a hair or a spine. There are, however, two conspicuous pores, which are similar to those containing hair, but devoid of them and much larger, being about 2 - 3 mms. in diameter. They are symmetrically located on the anteriormost part of the edge of the disc, one pore on either side of the median line, at a distance of about 3 cms. from one another, in an adult specimen (Text-fig. 1 Pl. I Fig. 4). A number of similar, smaller — but still larger than the pores lodging hair — and somewhat contiguous pores also occur on the lateral parts of the edge of the disc. These characteristic pores, which are of unknown significance, may be sensitive, but further investigation is necessary in order to disclose their function. They will be temporarily called the « terminal and lateral pores » respectively, and will be the subject of study at a later occasion, when specimens are available.

The head passes insensibly into the trunk, being separated from it by an externally not distinctly demarcated neck, which is slightly narrower than the head and broadens proximally.

The Flippers (Pl. II, figs. 1-3) :

The beginning of the trunk is marked externally by the flippers, which form the anterior extremities and arise at the ventral third of the height of the body, a little behind the ear openings. They are relatively short and weak and at rest they point obliquely downwards, outwards and a little backwards. Their junction with the trunk is provided with relatively much thinner skin which is thrown into some wrinkles, thus allowing a fair degree of mobility. The character of the flippers indicates that they are extensively used, not only in maintaining the equilibrium of the body during swimming, but also in other functions. In shape, they resemble an elongated pointed blade of an axe, narrowing to an acute angle at the tip. The flipper is straight at its anterior margin, which has a comparatively thick and rounded edge. From this side, the

flipper decreases gradually in thickness towards the posterior margin, which is not straight but rather curved. This posterior edge is thin, especially at the distal half which is hard, cornified and considerably sharp. At the distal angle of the flipper, the skin on the ventral side is distinctly calloused especially on the ventral edge and the tip. It is significant to consider all these characters, together with the internal anatomy of the flipper and its skeleton when discussing its function. Thus, the radius, the ulna, the metacarpals and phalanges are all separate and have normal and movable articulations, especially aided by retarded ossification of all the elements including the long bones, as well as the carpals, metacarpals and phalanges. Even the epiphyses remain isolated and independent and may even be duplicated. The phalanges and the mobility of their joints can be easily felt from the skin outside. It is not difficult, therefore, to conclude that the flippers play a more important rôle than has been attributed to them till now. The hard and sharp edge helps in digging out, from the sea-bottom, the roots of the sea-grasses on which the dugong feeds and collecting them together, raking them away from the mud.

The flippers may also be used for creeping over the bottom while grazing or resting as well as holding fast to the bottom when the water is too much agitated by waves or tidal currents, hence the callosities on the inner sides of their tips.

The Nipples (Pl. II figs. 1-3) :

There are only two nipples which are pectoral in position, and situated one on each side just behind the axilla. In this position, they are in concordance with the general stream-line of the body as their projection is blended with that of the flippers, and when the latter are folded, as during fast swimming, they completely cover the nipples.

In immature individuals, whether males or females, the nipples are hardly elevated above the general surface of the skin. Their place is indicated simply by their skin of slightly different colour, being more pinkish. As females approach maturity the nipples protrude until they become in adult non-pregnant females about 25 mm. long and 18 mms. in diameter at their base. During pregnancy the nipples grow in size and in a lactating female 288 cms. long they were cone-shaped, 85 mms. long and 55 mms. in diameter at the base, and when they were squeezed, milk squirted out with great force to a considerable distance. About 20 mls. of milk were easily obtained in this way, but unfortunately it was not possible to carry out any investigation on it.

Annandale (1905, p. 240) in a description of a male dugong from the Gulf of Manner stated that « the mammae, which were large considering the sex of the individual ..... were long in comparison with their diameter," and that « this elongated character of the mammae is characteristic of both sexes ». In the Red Sea Dugong, on the other hand, although the mammae are of an elongated character in the female, they are too rudimentary in the male to deserve being descripted as « elongated ».

The Trunk and Tail :

The circumference of the body — which is smallest at the beginning of the neck just behind the chin and the auditory region — increases gradually until the unbilical region is reached, where the diameter becomes largest, and then it again decreases gradually in the direction of the tail, becoming thinnest near the origin of the fluke, which occupies the hind third of the tail. The tail is strengthened by a low dermal ridge on the mid-dorsal line and another on the midventral line. The dorsal ridge is stronger than the ventral, the two being about 5 and 4 cms. respectively at their highest points. They are darker in colour and densely beset with short pickles. The tail ends in a relatively large horizontal tail-fin, formed by the yind third of the tail. This fin is subject to great individual variation, varying from a roughly triangular shape to a somewhat crecentic form, with the lateral points extending by only 6 - 10 cms., beyond the middle point, where there may be a little notch. The fluke consists wholly of fat and gristle, and in its median part, the vertebral column ends. It is proportionately much greater than in the Cetacea; as in the dugong, its width may attain, more than one third of the length of the body.

At the posterior end of the trunk, on the mid-ventral line, lies the anus which is a puckered opening, more or less elongated in the cranio-caudal direction, and about 5 - 6 cms. long in the adults. The opening leads into a very shallow sinus in the antero-dorsal corner of which is a small funnel-shaped blind depression of unknown significance, and into the corner opposite to this funnel, opens what Osman Hill (1945, p. 161) calls the anal canal. This canal may simply be the outer end of the rectum. The opening of this canal into the anal sinus is small, about 1.5 cms. in diameter, well-defined and — as described by Hill — tightly closed by the folds, which get abruptly high and slightly thickened near that opening. In my specimens the rectal — or anal according to Hill — canal was only 2.5 - 3 cms. long and about 1.5 cms. wide, and the swellings at the end of the folds cannot be described as globular.

SKIN

The skin is thick all over the body. It is thicker on the dorsal side where it is a little less than double the thickness of that on the ventral side. In a female specimen 288 cms. in length the skin was 35 mm. thick on the back and 25 mms. on the belly. The epidermis is relatively thin and, on the belly, of the specimen mentioned above, it was 2.5 mms. in thickness. It has a well-developed **rete mucosum** with a layer of columnar cells at the bottom covered by several layers of polyhedral cells, which gradually flatten down externally. In the **stratum granulosum** the cells become more flattened than in the skin of most other animals. In fact, **here** the cells look, in sections, so elongated that they recall unstriped muscle fibres. Their nuclei are similarly greatly flattened.

A **stratum lucidum** is seldom distinguishable. The **stratum cornium** is composed of a few layers of extremely flattened cells, which have lost their nuclei and got firmly attached to their neighbours in the same layer. Cells of successive layers, however, show a tendency towards separation; a tendency which increases from inside outwards, so that the outher layers slough off readily in thin translucent membranes, especially after the death of the animal.

The **cutis vera** is intense white and constitutes the main part of the thickness of the skin. It is composed, peripherally, of dense vascular connective tissue, underlying the epidermis. It sends several microscopic papillae into the **rete mucosum,** which may penetrate throughout the entire thickness of the latter, carrying blood capillaries and nerve fibres, and extending to the **stratum granulosum.** The basal layer of columnar cells of the **rete mucosum** is moulded over these papillae and attached to them.

The **corium** becomes less dense in texture as we go deeper and finally merges into the **panniculus adiposus,** constituting the blubber. This is not so well developped here as it is in the majority of the Cetacea, as the dugong is principally a warm water inhabitant and does not need as much protection against loss of heat as do the whales, whose fats also have lower degrees of liquifaction.

Considerable amounts of fat occur, also, in the connective tissue of the omentum and below the peritoneal lining of the coelom. So much fat may be stored under the peritoneal membrane of the body wall that it protudes as low ridges between the intestinal loops, so that when the abdominal wall is reflected the impression of the intestinal loops on its inner surface strike the attention.

During the last century, medicinal properties were attributed to dugong oil. It was recommended as a theurapeutic agent and as a substitute for cod-liver-oil, as it was supposed to possess all the advantages, but without the unpleasant smell and taste, of the latter. No large supply of this oil could, however, be obtained, so that the price went high, and adulteration became frequent, and consequently the oil lost any reputation it may have merited, and dropped out of use.

Old fishermen of the Red Sea state that the oil is good for cooking purposes. In fact it has a characteristic but pleasant smell and its taste is fine. It also keeps exceptionally well without special treatment and may hold for some few years without getting rancid.

It was therefore deemed desirable to test some of the properties of dugong fat and to compare these with those of other common fats. The omentum which had been salted and left to dry was heated to a temperature of 70-80°C, and the fat filtered while hot. The results are summerized in the following table :

	Dugong fat	Nutton fat	Suet or Tallow	Beef fat	Eard
Refractive Index at 4°C.	1 457	1.445—55	1.447—55	1.447—49	1.449—1.452
Acid Value	0.15	—	—	—	—
Saponification Value	194.8	194—200	193—200	193—202	193—199
Iodine Value.	58	35—44	35—44	38—50	57—68
Reichert Meissle Value	0.88	Less than 1	0.5—0.9	—	—
Polenski Value	0.6	trace	0.5—0.6	—	—
Unsaponifiable matter	0.82	0.2—0.7	0.2—0.4	0.2	0.4

From the above table it is clear that dugong fat approaches lard most.

HAIR AND SPINES

As a protection for the skin, during browsing, the flat surface of the muzzle is armed with especially numerous bristle-like hairs, the majority of which are short (4-6 mms. in length) a little curved, relatively weak and moderately spaced (4-6 mms. apart). Each arises from a follicle lying at the bottom of a tubular somewhat larger depression. The strongest hairs are spine-like and are found above the antero-lateral parts of the mouth, where three or four, not quite regular, rows of them occur. These spines are relatively very stiff, somewhat pointed, slightly

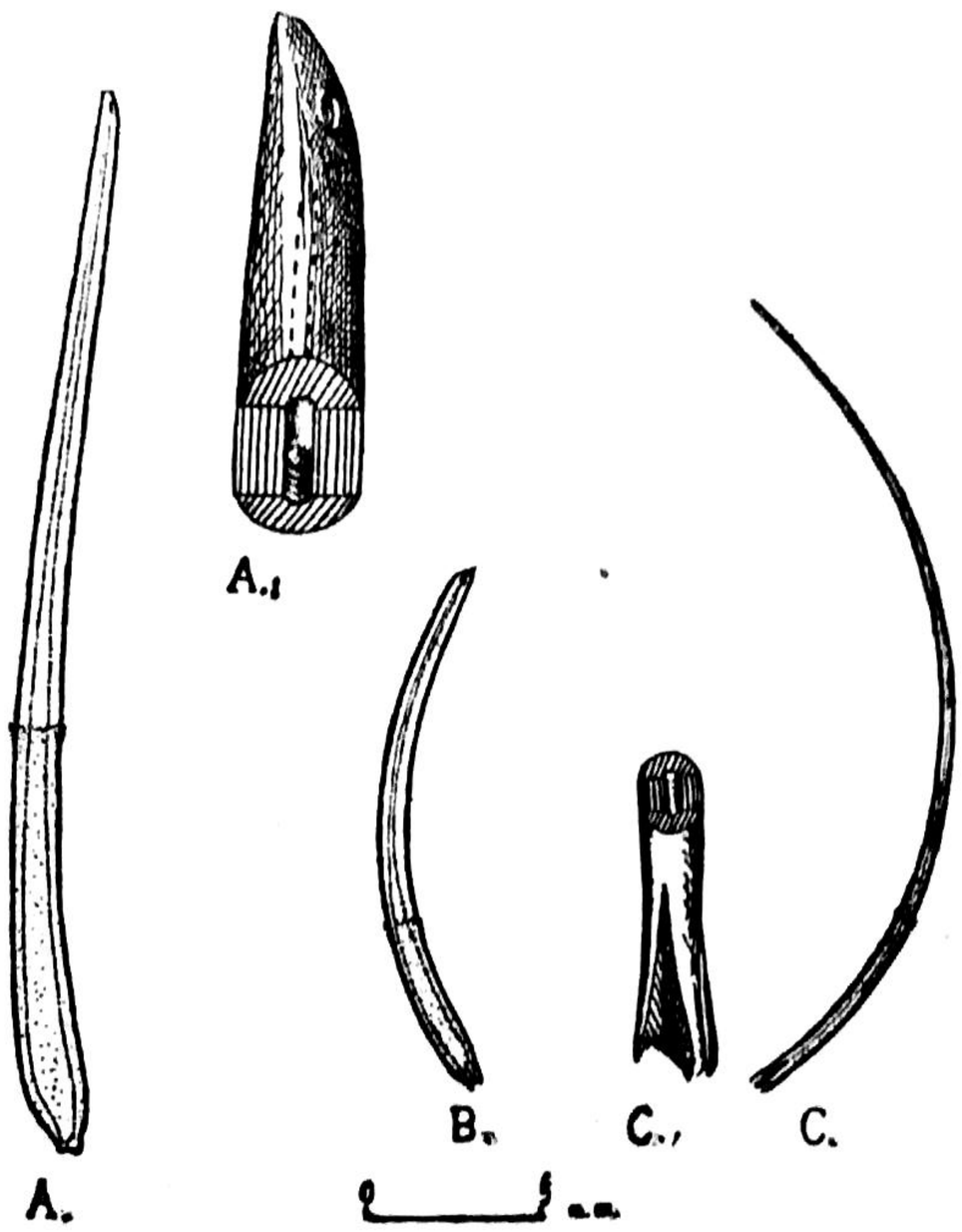
curved, and may attain a length of 2 cms. or more. These strong spines — besides their protective function — apparently help in rasping sea-grasses from the muddy bottom. This can be evidenced by the fact that the tips of these hairs are always worn out, so much, that the medulla shows to the outside through a hole at the tip of the cortex produced by wearing. Hanging from the upper lip, at the postero-lateral angles of the mouth, are much longer and thinner but fairly stiff bristles. These are also much more densely crowded than anywhere else, and form, on each side, at the corners of the mouth a brush-like structure, which probably subserves the function of filtering out the sea water together with the mud taken in with the sea-grasses while feeding. On the lower lip, in the groove between the muco-cutaneous portion and the truly mucous part, can be seen a row of especially strong and long spines which lie, at rest, for the most part hidden in the groove. On the «chin» hairs are less numerous than on the parts just described, but still more abundant than on other parts of the body with the exception of the dorsal tail ridge. The chin hairs are long and of moderate strength. They are longest at a little distance from the mouth and decrease gradually in number as well as length as we pass farther from the mouth (Text fig. 1). Hairs round the mouth, on the muzzle and on the chin evidently have also sensory function.

According to Hill, in dugongs from Ceylon these hairs and spines on the muzzle « are the only representatives on the animal of a pilious system, except for some minute bristles on the chin, on the dorsal surface of the animal and around the anus and genital openings", (Hill 1945, p. 154). In the Red Sea dugong, hairs are also present, though sparse, on the dorsal side of the head, the neck, the flippers and the rest of the body and their distribution and character vary from part to part. Only a few areas are totally devoid of hairs, such as the axilla, small areas behind thè nostrils, round the ear openings, and there are only very few hairs around the anus and external genitalia. The ventral surfaces of the flippers are also almost, but not completely, devoid of hair. On the dorsal side of the head, in front of the nasal openings, hairs are fairly long (10-13 mms.), but weak and spaced at distances about 10 mms. apart. They get shorter and more widely spaced backwards. On the dorsal surface of the trunk, they are slightly stronger and are 30-50 mms. apart. Here they are also interespersed with more numerous pore-like follicles, dispersed at distances of only 5-8 mms., rarely more. Out of each of these follicles protrudes teh tip of a minute bristle-like hair, not more than 1 mm. long. These give the dorsal surface of the trunk a prickly appearance and touch, especially in dried skins. A few of the follicles have no hairs or bristles and their hairs may have fallen off and

have not yet been replaced, or, they may belong to rudimentary hairs. The uniformity of the character of the minute bristlets and their much greater numbers, as well as the lack of intermediate forms between them and normal hairs exclude the possibility of their being simply younger, or replacement hairs in process of growth. Hairs on the ventral side of the trunk are of the same type as those of the dorsal though slightly weaker; and the interspersed follicles are not much more numerous than those with long hairs and are generally without the characteristic prickles or bristlets of the dorsal surface. The distribution of hair on the tail is similar to that on the trunk except for the caudal ridges. On the edges

Text.-fig. 1 : Ventral view of head of dugong, with the mouth opened to show the lower horny plate, the hard wart-like processes (W.Pr.) distal to the upper plate, the oral brush-like bristles on the sides of the mouth. The row of strong bristles (Brs.) on the lower lip, the muzzle (Mz.) and its sulci (Sl.), bristles and hairs are also shown.

of these ridges hairs are only of the short prickly type and are much crowded on the dorsal, being 1.5 to 2 mms. apart, but less crowded on the ventral 2 to 3 mms. apart. These ridges look, therefore, more prickly and darker in colour than the rest of the body. Hairs and spines are of the same colour and of the same morphological structure (text - fig. 2). Thus the two types are creamy white and almost devoid of pigment; and although they are all rough to touch, they — spines and hair — are rather weak and therefore easily break off. Thus, the fact that dugongs' hair is readily lost, during preparation of skins and mounts, is due to breakage rather than to their being shallow-rooted in the skin and therefore being readily pulled out, as has been suggested by some authors. In fact, it requires special care to pull the hair or spines out of their follicles without breakage.



Text-fig. 2 : Bristles and hairs of G. the dugong A., one of the longest bristles from the lateral lobe of the muzzle hanging over the mouth; A_1 apex of same, magnified and seetioned; B, shost bristle from muzzle; C, hair from dorsal surface of body; C_1 root of same, magnified and sectioned.

In structure, hair and spines of the Red Sea dugong differ but slightly from the description given by Hill (1945). Hair and spines agree fully in structure among themselves, but differ only in thickness. They consist of an external creamy white cortex surrounding a dirty brown pulpy medulla (text - fig. 2). They are more or less bowed and increase gradually and regularly in diameter from the tip to the root and, in this respect, they differ from those of the dugongs of Ceylon where Hill described the roots as distinctly swollen and funnel-shaped. There is hardly any thinning of the horny cortex layer in the root of spines but the base of the roots of ordinary hairs is thinned out so that it collapses when the hair is pulled out of its follicle. More than half the length of spines is imbedded in the skin, but of the long hairs not more than one third is embedded in it.

THE HORNY PLATES

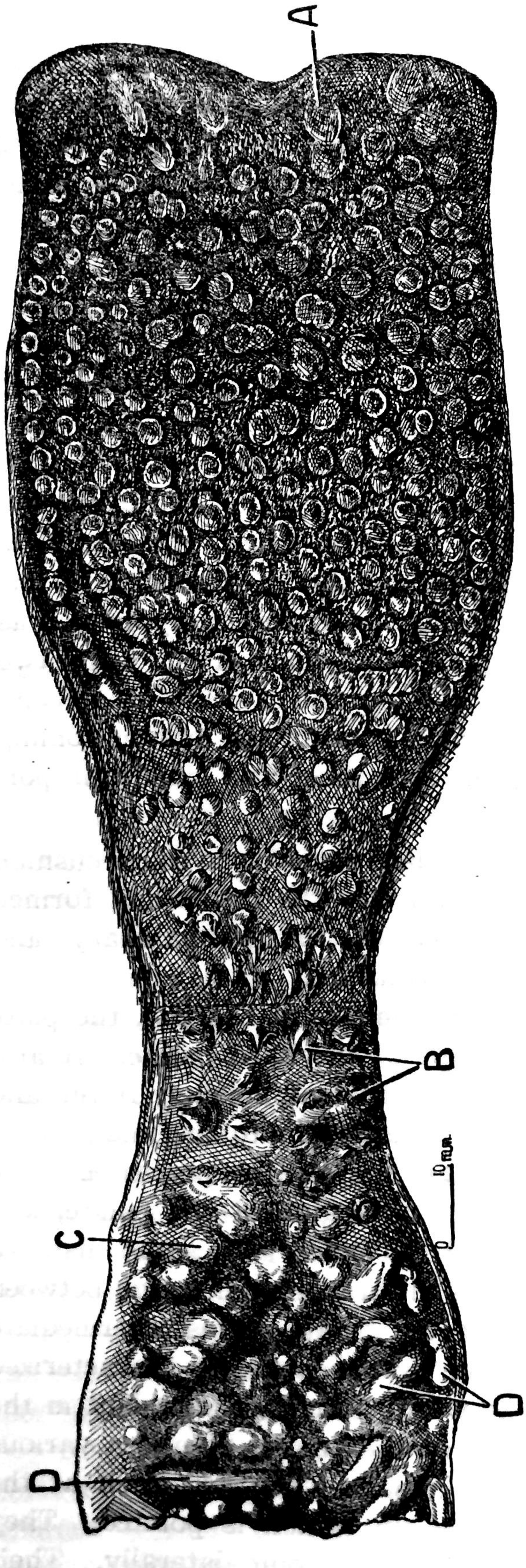
Among the important structures characteristic of the Sirenia are the so-called « horny plates ». The development of these plates has accompanied the progressive reduction of dentition encountered in this order, as well as the strengthening, increase of size and deflection of the jaw-bones. Of these « horny plates », only the lower one forms a fully developed and well-defined organ, the upper is not advanced as far, and may be considered as only an intermediate stage between a fully-formed organ and a special development of the buccal mucous membrane of the hard ptate. The development of the plates, especially the upper, may have been more advanced in the completely edentulous extinct sirenian genus *Rhytina*; but of this we have no full description.

In spite of their great importance in the Sirenia, these plates have not received enough attention and their description still needs to be enlarged.

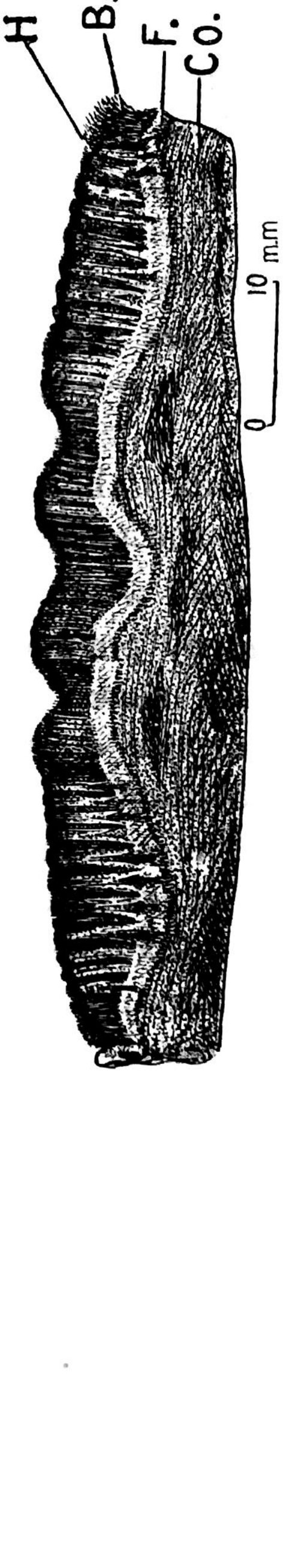
The two plates lie opposed to one another, in the fore-part of the mouth on the deflected portions of the jaw-bones, mainly in the toothless part of the mouth.

The upper plate (Text - figs. 3 and 4) :

The upper plate lies mainly on the palatine processes of the excessively grown premaxillary bones, and continues for a short distance over the palatine processes of the maxillaries. It starts from behind the protruding alveolus of the upper jaw and extends to a short distance before the angle of deflection of the jaw. It is precedded, on the oral side of the alveolus, by a number of stout and hard-cornified processes disposed in transverse rows, of different number and arrangement. In one case there were 7 such processes in two rows, an anterior of four processes and a posterior of three, lying alternatingly with those of the first row (text - fig. 1). The main part of the upper plate itself is roughly rectangular, the sides being straight and parallel, while the anterior end is also generally straight and perpendicular to the side. It, also, often has either one median shallow notch, or two such notches, dividing the anterior edge of the plate into two or three roughly equal parts. The corners are also rounded. The surface of this plate is exceedingly rough, owing to the presence of innumerable hard bristles. In colour it is dark, almost blackish in old individuals and lighter (greenish) in younger ones,



Text fig. 3 : The upper horny plate. A, horny dome-like protuberances ; B, claw-like or nail-like horny processes ; C, rounded fleshy warts ; D, elongated fleshy warts.



Text-fig. 4 : Transverse section in upper horny plate. D, dome-like projections ; B, bristles ; Co. corium ; F, follicular layer ; H, Horny layer.

which also have correspondingly less developed bristles. Especially in full-grown animals, the whole surface is studded with dome-like irregularly arranged prominences, which are large in the median zone, where they are about 4 mms. in diameter, gradually decreasing is size laterally to a diameter of about 2 mms. These prominences are equally covered with bristles, which are, as a rule, more worn out than those in the areas in between the warts. In a free-hand section this plate is seen to rest on a fairly thick corium composed of dense and tough connective tissue. Stretching on this corium is a thin and somewhat undulating layer, about 1 mm. thick, formed by the densely packed follicles of the plate bristles, which give it a distinctly striped appearance. These bristles are formed of the normal constituents; viz, a medulla in the middle which is slightly darker in colour, surrounded by a translucent cortex. Above this follicular layer is a thick horny layer, similarly wavy, and formed of a glassy translucent substance, having a brownish tinge. This layer is 2-3 mms. thick and in it is embedded the major part of the length of the bristles. In the sites of the dome-like prominences, the horny as well as the follicular layer evaginates, forming a hollow dome of the same two layers — the follicular and the horny — and into the cavity of this evagination extends a thick principal papilla of the corium; the bristles coming out all over the surface of the dome, and into them also extend proportionately small papillae of the corium.

The horny plate covering the hard palate rests on a thick cushion of connective tissue which, in its turn, fits into the depression formed for this purpose on the palatine surfaces of the premaxillary and maxillary bones to which they are firmly attached.

Inside the mouth, at the region of the flexure of the jaw, the plate narrows down sharply, following the shape of the hard palate. It also decreases in thickness and the prominences become smaller, fewer and more widely separated, as the plate passes insensibly into the middle part of the hard palate, supported by the middle or the palatine processes of the maxillary bones. This part is the narrowest region of the palate, and begins about the flexure of the jaw and continues to a short distance before the origin of the molars. It forms the transitional region between the horny plate and the hinder part of the palate. This intermediate part is devoid of both the bristles and the prominences but characterized by peculiar structures. In place of the warts which are abundant in the anterior as well as the posterior regions of the palate, here is a various number of very hard, strong horny processes. They are thick at the base, thinning out gradually towards the tip, which is pointed. They are claw-like being bent backwards but a few point laterally. Their

number varies between 10 and 25, arranged in 4 or 5 irregular transverse rows. They are mostly solitary but a few may occur in pairs.

It is difficult to understand the function of these claw-like structures in the intermediate region of the palate. In some specimens they are sharp and long (7 or 8 mms. long), in others they are short, worn out and blunt. Intermediate conditions, naturally, also occur.

The hind region of the palate is wider than the intermediary, and only a little narrower than the anterior horny portion. It is fleshy and produced into numerous warts of various sizes and different shapes, though they tend to be circular or oval in outline. Rarely two or three warts may flow into one another forming a ridge. This fleshy part covers the internal end of the hard palate and may extend a little behind it to take a small part in the formation of the soft palate.

The soft palate is formed of a fairly thick, fleshy and somewhat soft membrane. The anterior part of it is smooth, but the posterior is rough and covered with minute papillae.

The Lower Plate (Text - figs. 1, 5 and Pl. I, fig. 4) :

The lower plate, or the horny plate proper, is externally better demarcated from the surrounding tissue than the upper and is distinctly raised above the general surface. It is also differentiated earlier in the ontogeny of the animal and constitutes a well-defined organ. Thus in the young specimen 110 cms. long, the membrane covering the roof of the mouth was but slightly hardened and possessed only a few low warts. On the other hand, the lower plate was completely developed and constituted a well-defined organ.

Anteriorly the plate is pointed to a tip, gradually widen out posteriorly, in straight sides, until it reaches its greatest breadth at a point a little less than two thirds its length from that tip. At this broadest point, the plate is one and a quarter times as broad as the greatest breadth of the upper plate. Beyond this, the sides curve inwards to meet one another, each roughly describing an almost quarter circle. At the meeting place, these two quarter circles form a somewhat deep notch, which in a full-grown specimen may be about 1 cm. deep and about the same in greatest width. The shape of the whole plate is more or less like that of a cordate leaf.

In young individuals the plate is dirty greenish in colour, obviously coloured by the juices of the chewn up sea-grasses, but in full-grown animals — where it attains the dimensions of 11 Cms. long by 6.5 Cms. wide — it turns blackish in colour and also has a rougher appearance.

Along its median line the plate has a long gutter-like depression, bounded on either side by a little raised ridge-like edge. The depression stops short of reaching the anterior tip of the plate, where the raised edges on the two sides may continue into one another or may die out gradually to end together with the median groove flush with the surface of the organ. Another two grooves parallel to the median one occur lateral to, and on either side of it. Internally, the main or median groove continues into the posterior notch whereas the surrounding ridges and lateral grooves continue towards the end of the plate, where they die out gradually.

The entire surface of the plate is exceedingly rough, being densely and uniformly beset with minute bristles, giving it a file-like structure. The internal edge of the plate bends slightly downwards for a distance of a few millimeters, where it is overlapped by the tip of the tongue.

Owing to the fact that this plate is taking an increasing part in the process of triturating the food of the animal as a result of the reduction of teeth, it has become of great importance that the plate be firmly fixed in its place, more so than in the case of the manatee which has more numerous and better developed teeth. This state of affairs is clearly seen in the anatomical modifications that accompany the development of this plate. Thus we find that the plate has a well developed support of stout bony structures.

The mandibles which are particularly massive, get still thicker near the symphysis, and the two rami are firmly ankylosed together with a long and strong symphysis. The extensive oral edge of the symphysis is sharply bent obliquely downwards, to oppose the similarly deflected premaxillary bones in the upper jaw. Here, the dentary bones widen out considerably towards the oral surface of the symphysial region, into, a broad and flat surface. This broadening does not envolve the outermost end of the deflected portion of the mandilulars, and the surface thus produced has a leaf-like shape similar, and equal in size, to that of the superimposed horny plate.

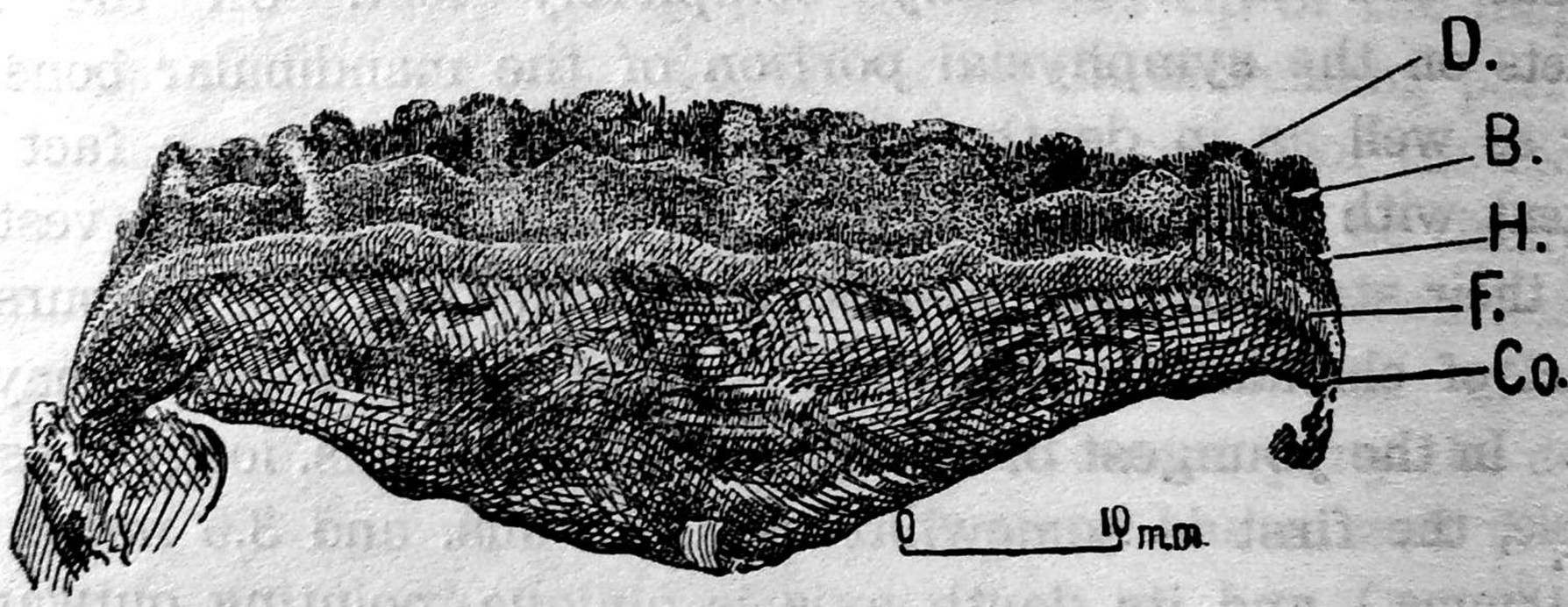
Perhaps the most important development in this respect is connected with the sockets of the abortive teeth of the lower jaw. In the region of the mandibular symphysis below the horny plate, there are a series of tooth-sockets, often four in number on each side of the symphysis. In all the jaws that I have in my possession from the Red Sea, these sockets do not contain any traces of teeth, although several authors, (Owen 1866, III p. 284 and 11 fig. 160, Fernand, 1953, p. 144 and others), described the presence of abortive teeth in at least some of them, and these teeth are evidently without function as they are covered by the horny plate. It may also be mentioned that I found one such tooth in

the third socket of the right mandible of the female skull in the British Museum obtained from ʿAqaba, at the tip of the Gulf of ʿAqaba in the Red Sea. The tooth was rod-shaped about 3 cms. in length and was inserted in a cavity in the socket of similar size. The rest of the socket was full of bony trabeculae.

The alveoli of these abortive teeth have always been looked upon as vestigial, and no further significance has, therefore, ever been attached to them. In fact, had there been no function subserved by these sockets, they would have had gradually disappeared, especially in the absence of teeth, which is the case in, at least, the majority of them. This is what happens to the alveoli of other deciduous teeth of the dugong eg. the deciduous upper incisor and the deciduous molars where, after loss of the tooth, the socket is gradually filled up with bone tissue and is eventually completely lost. On the contrary, the sockets on the symphysial portion of the mandibular bone grow in diameter as well as in depth with the advance of age, a fact which is inconsistent with the view that they are functionless and vestigial. A study of their structure and relations had, therefore, to be pursued with the object of elucidating whatever function these sockets may be performing. In the youngest of my specimens (110 cms. long) these sockets are simple, the first is somewhat oval, 6 mms. and 3.5 mms. wide. It is deep (8mms.) and its depth axis is oblique, pointing outwards. The other three sockets are circular, 7, 6 and 5 mms. in diameter respectively, they are shallower than the previous, 3-4 mms. deep. All of the four sockets are simple pits without any special development. As the animal grows, the lateral broadening of the oral area of the symphysis increases and the leaf-shaped surface correspondingly enlarges. The sockets also keep pace with this growth and widen out to fill all available space without losing the regularity of the circular outline of nos. 2 to 4; but the outermost pair of sockets increase more in the lengthwise direction. All of them also increase in depth. The simple internal structure of the sockets becomes gradually complicated by the growth of numerous irregular long bony trabeculae growing from the periphery towards the centre. With further growth, the sockets still grow further in size, and the trabeculae also grow, but more and more irregularly, anastomosing at the same time and acquiring conspicuous perforations, eventually giving rise to a sponge-work which almost completely fills the cavity of the enlarged socket (Text fig. 6). These porous bony structures aid, no doubt, to fix the horny plate tightly in its position. It is thus seen that the horny plate is attached by a strong, thick and tough connective tissue layer to a

thin layer of cartillage covering the surface of the mandibular symphysis and that this connective tissue layer swells out as a thick pad over the opening of each socket. From these extend pads of strong connective tissue strands and cords, that branch and intertwine with the bony sponge-work filling all the interspaces in the sockets.

It is thus seen that the sockets of the abortive teeth of the lower jaw, far from being merely vestigial structures, have really a very important function of solidly pitching down the horny plate in position. Such fixation self-evidently ensures better functioning of the organ. It also indicates the fundamental rôle played by this organ in the comminution of the food, a function which has been taken on by this organ as a result of the reduction in the number of molar teeth as well as the deficiency of their enamel.

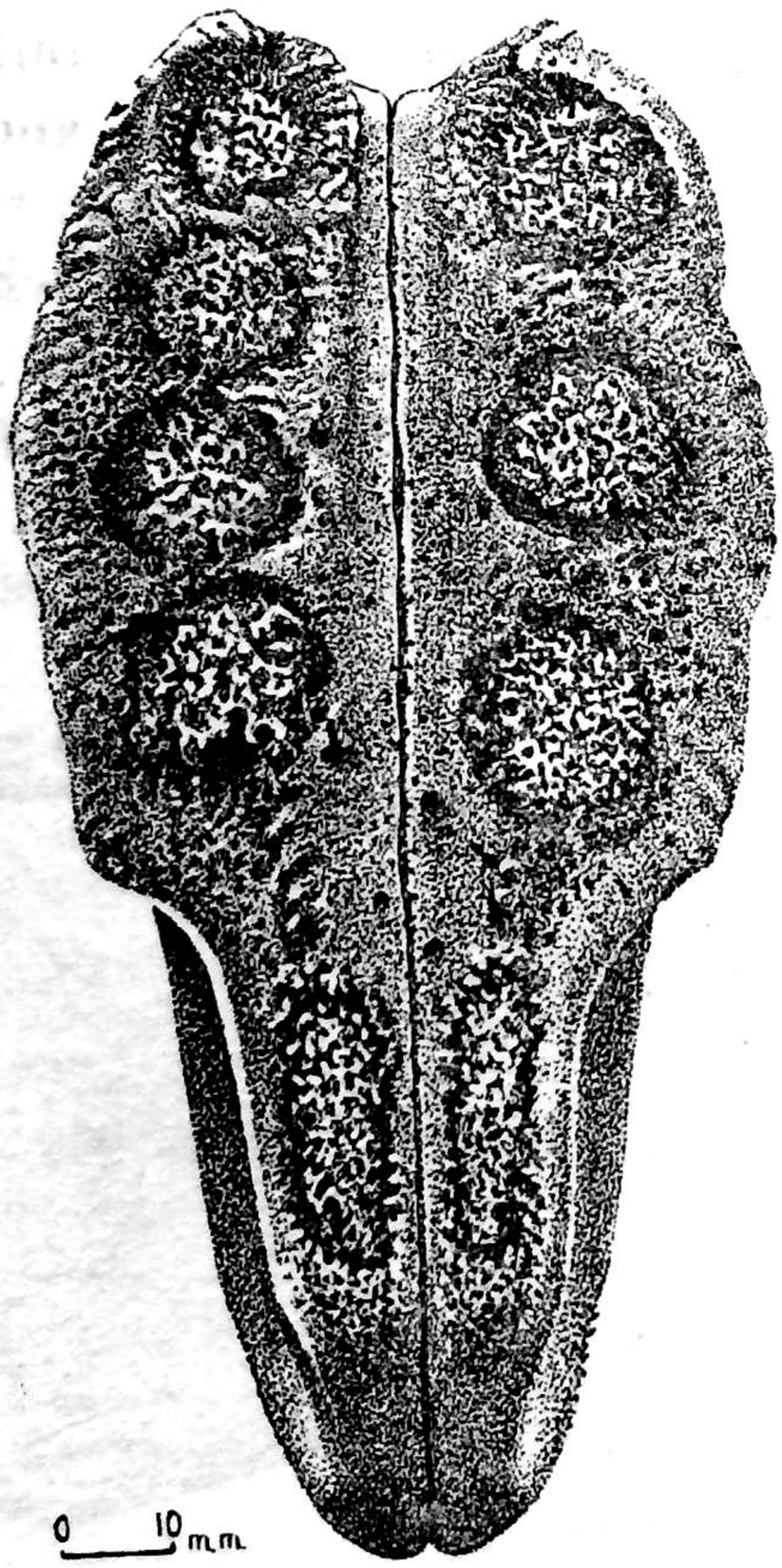


Text-fig. 5 : Transverse section in lower horny plate. B. bristles; Co, corium; D, dome-like projections; F. follicullar layer; H. horny layer

The structure of the plate itself is interesting. It represents a special development of the mucous membrane of the mouth. The corium, which is fairly thick, is formed of dense and tough connective tissue. On top of this is a layer of uniform thickness consistuted mainly by the follicles of the innumerable bristle-like hairs which lie so densely crowded that they are tightly packed together (Text - fig. 5). These bristles are formed of the normal structure, a medulla in the centre surrounded by the translucent cortex. This follicular layer is covered by a hard thick horny layer formed of a somewhat glassy-transparent substance in which the greatest part of the length of the hairs is embedded and thus firmly cemented together and greatly strengthened. This layer is two to three times the thickness of the follicular layer. The hairs within this layer are grouped in bundles of 6-10 bristles, rarely more, arranged in circles. The free parts of the bristles vary in length according to the state of wearing of the organ and the position of the bristles. They may be so short as to constitute but slight elevations over the general surface of the horny layer, elevations which recall diminutive tubercles of molar

teeth; or they may be just long enough to give the organ an appearance like that of a hard scrubbing brush. All kinds of intermediate stages occur, but at the lateral edges of the plate the free portions of hairs are usually longer, and less arranged in groups, than in other parts.

The lower plate begins a little anterior to the upper, opposite to the horny processes in front of the latter. Its greatest breadth is also greater being about one and a quarter times that of the upper. This indicates that the lower jaw can move in a somewhat circular direction, or sideways as well as lengthwise against the upper during mastication. This is also reflected in the articulation of the jaw; the condyle of which is, thus larger and more or less flat, while the glenoid cavity of the squamosal does not deserve being called cavity. It is large and almost flat being broad and only slightly concave medio-laterally, but also short and, slightly convex cranio-caudally.



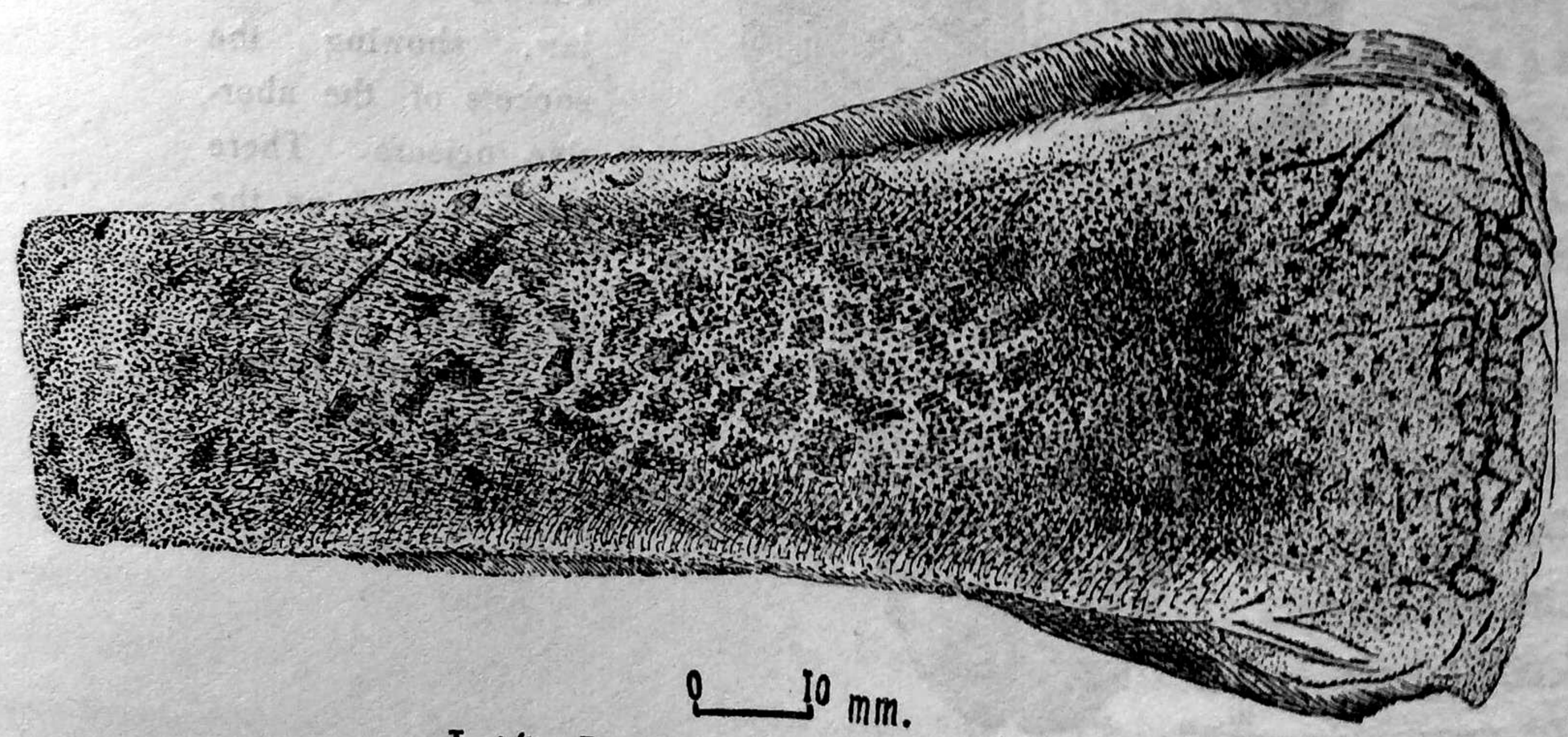
Text-fig. 6: Anterior view of the deflected surface of the lower jaw, showing the sockets of the abortive incisors. There are 5 sockets on the right and 4 on the left sides. They are all filled with spongy bone tissue.

Around the lower horny plate there are strong spines about 7 - 10 mms. long and 3 - 5 mms. apart and mostly arranged in one row surrounding the plate except for the hinder edge where there are no spines or hair. The buccal mucous membrane joining the upper and lower horny plates along the sides of the mouth is provided with numerous long hairs, more than 10 mms. long and 2-3 mms. apart.

The Tongue (Text - figs. 8-13) :

The tongue directly follows the lower horny plate, and in fact its anterior tip overlaps the hind edge of the plate. This edge is bent slightly downwards under the tip of the tongue which is also thinned out so that the upper surface of the horny plate passes in one and the same level into the dorsum of the tongue.

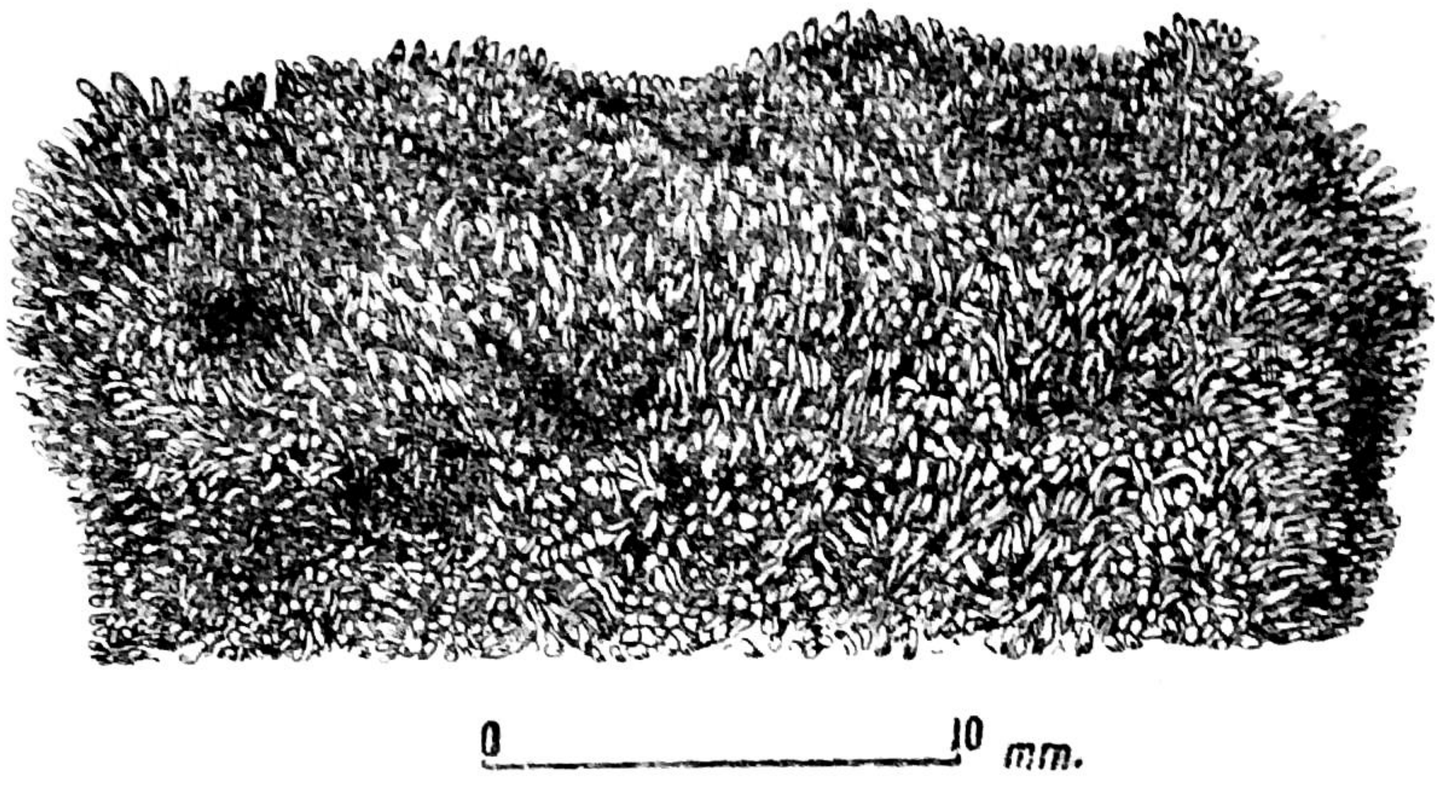
The tongue is very small as compared with the size of the body. It is particularly short, especially as it does not extend over the anterior part of the mouth, the part which is floored by the lower horny plate. The tongue is also narrow on account of the narrowness of the space between the mandibular rami. It is also fixed throughout the major part of its length and breadth to the floor of the mouth; not more than two centimetres of the anterior tip and a few millimitres along the sides of the lower surface being free. The tongue is, therefore, very feebly mobile, and does not reach the antetrior part of the mouth. There is no **fraenum linguae.** The tongue is narrower in front and widens out gradually backwards, until about two thirds its length, and then broadens more rapidly to attain, near its posterior end, a width which is about double that of the anterior part. Thus the tongue of an adult animal was about 14 cms. long and had a breadth of 30 mms. at the tip, 36 mms. at the middle of its length, 40 mms. at two thirds the length and 59 mms. near its posterior end (Text - fig. 7).



Text-fig. 7 : Dorsal view of the tongue

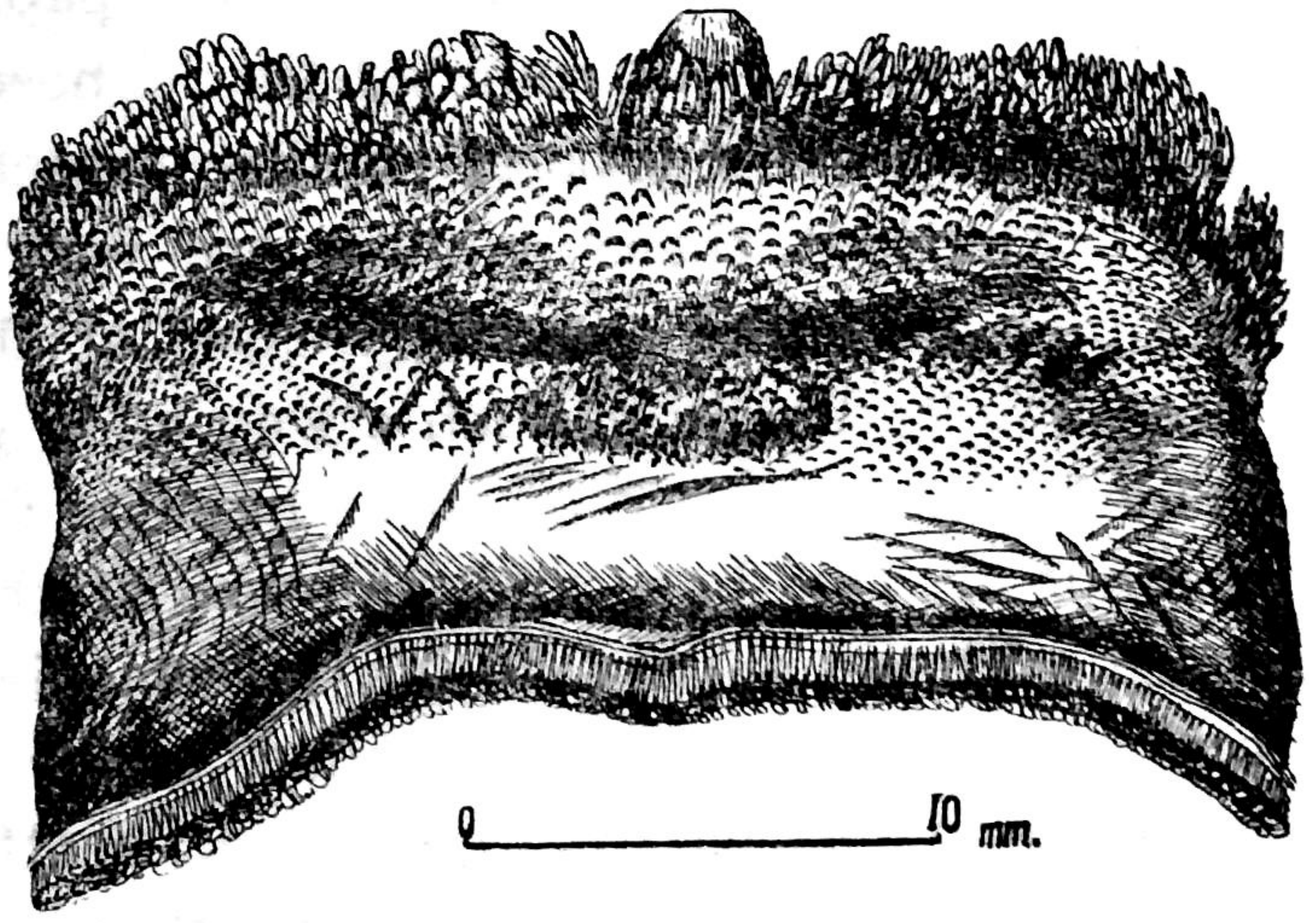
The dorsum of the tongue is strongly bowed antero-posteriorly. The free anterior end and a narrow strip on either side of the tongue are more or less flat, but the part of the dorsum between these is strongly arched from side to side, and between the arch and the lateral flat strips on each side, is a slightly depressed line, running parallel to the lateral edges

of the tongue. In the middle third of the tongue, the surface of the arched part of the dorsum shows a characteristic pattern. This is formed by the division of its surface into small roughly tetragonal or polygonal depressed areas separated by slightly elevated but conspicuous ridges (Text-fig. 7). These are lacking in the anterior and posterior parts of



Text-fig 8 : The dorsal surface of the tip of the tongue, showing bristles in front, followed by digitiform papillae.

the dorsum as well as on the lateral borders. In the anterior third of the tongue these depressed areas may be represented by irregular feeble depressions of various sizes, and separated by distances equal to or greater than their own diameter. The anterior tip of the tongue is not pointed, nor is it bifid as described by Hill (1945, p. 159), it is truncated



Text-fig. 9 : The lower surface of the tip of the tongue, showing a protuberance about the middle of the edge, horny bristles in front followed by wart-like papillae, and a smooth area behind.

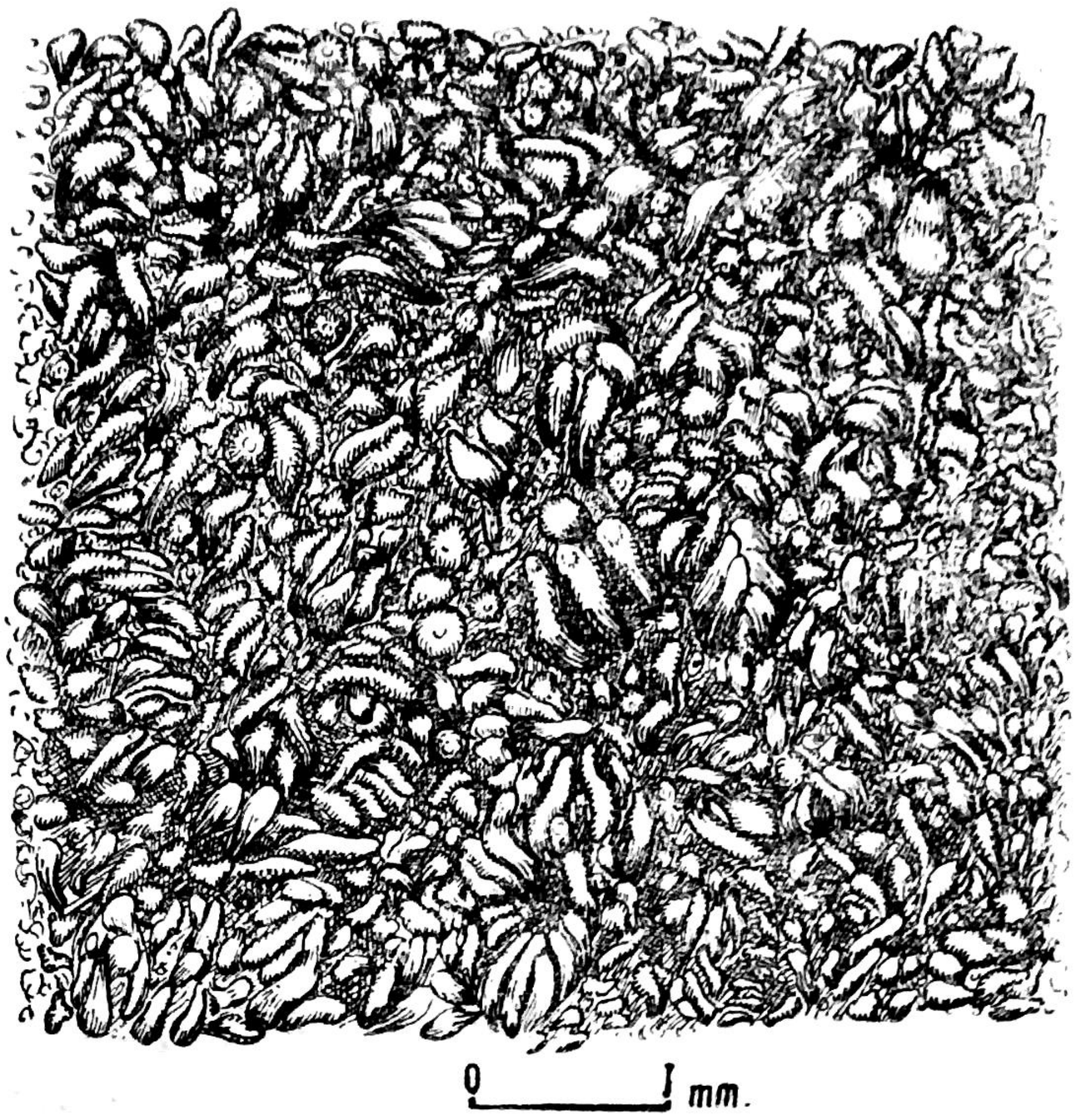
(Text - Figs. 7 and 8) and its edge may be slightly wavy instead of being quite straight. One or two, or even more, feeble notches or small protuberances may also occur on the tip (Text - fig. 9). The anterior edge of the tongue is also very thin and hard, being cornified and nail-like. From this thin edge, the thickness of the tongue gradually increases

backwards, and the organ, in this respect, is wedge-shaped. The greatest thickness is attained about the middle of the length of the tongue, where it may be about 3.5 cms. (Text - fig. 13).

The cornified tip of the tongue is dark-brown in colour and may be somewhat sharp. In adults it extends to a little less than one centimetre. In young individuals it is smooth but with the advance of age it develops stiff bristles and becomes rasp-like in appearance. These bristles are long on the tip proper, but are longer on the upper surface, and all of them point upwards. The few anteriormost rows of bristles on the lower surface are fairly long and point forwards. The following bristles decrease gradually in length posteriorly, until the only visible signs of them that remain are the brown spots, almost flush with the general surface. Behind this is a smooth strip extending to the point of junction of the tongue to the floor of the mouth. The bristles of the lower surface seem to wear out continuously, by working in relation with those of the lower horny plate. The structure of the horny layer and the bristles, as seen in a longitudinal section of the tip of the tongue, recalls that of the horny plate. The horn here is thickest at the tip proper, decreases gradually in thickness backwards, but it is thicker and extends farther backwards on the lower surface than on the upper (Text - fig. 9). Well developed dermal papillae extend into the bristles, as described in the case of the bristles of the horny plates.

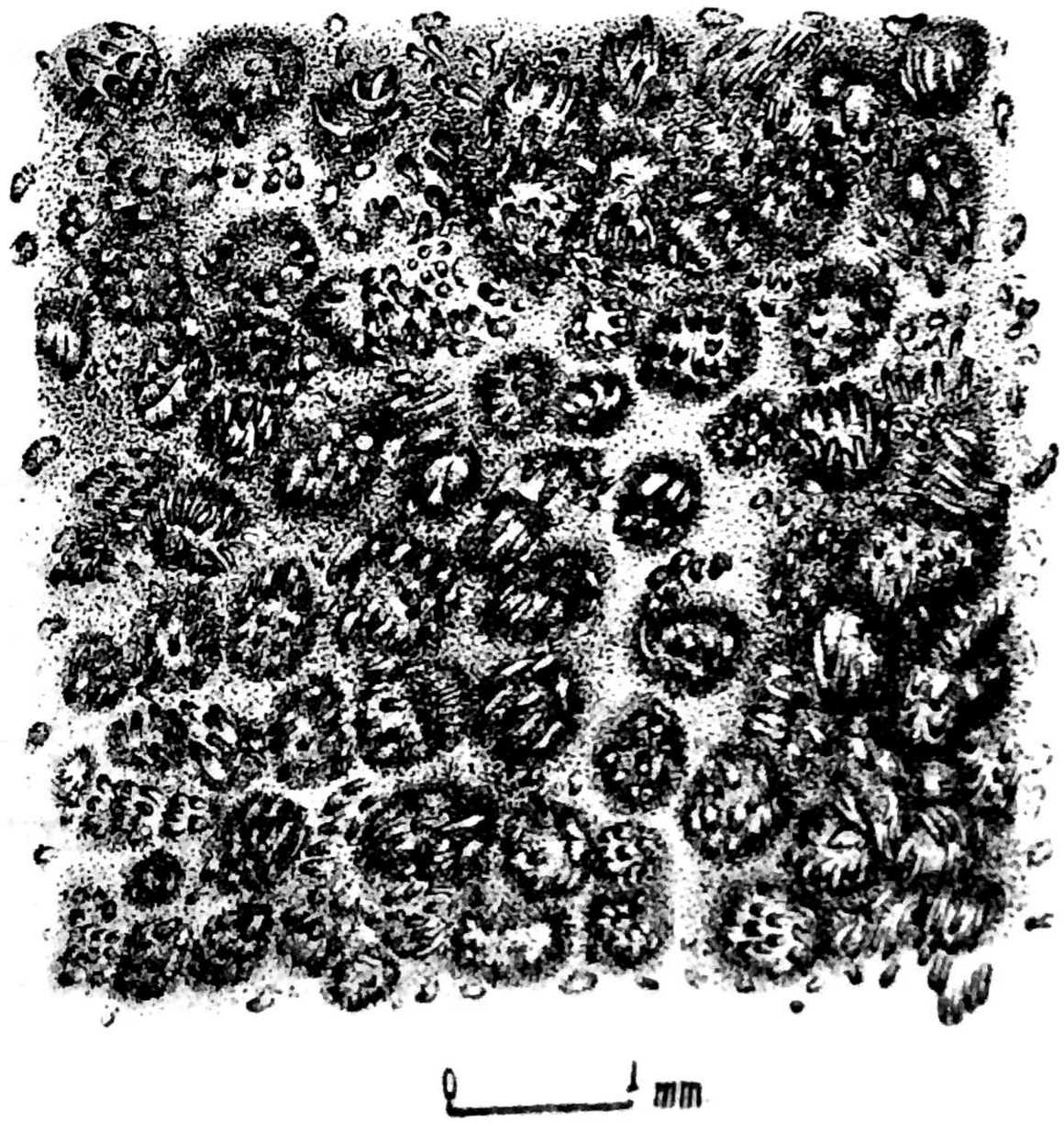
The dorsum of the tongue is thickly beset with soft papillae. These are simple in the anterior third, where the papillae are especially long and taper gently to a thin but rounded tip. These correspond to the conical papillae, the commonest type of papillae present on the tongue of various mammals. Amongst these papillae are very few which are digitiform and some may be broad and compressed at the top, where they may be constricted longitudinally in such a way as to give the impression of their being made up each of two or three papillae fused together. Others still may be stout at the base and thinner at the tip, having pear-shaped appearance. These appear to be intermediate, in form, between the digitiform and the fungiform papillae, which, latter are present in very small numbers in this part of the tongue, scattered here and there among the commoner types. The low lateral strips on the sides of the dorsum possess less numerous papillae, which are as a rule of the digitiform type but more attenuated, and of slightly smaller size than those described above (Text. - fig. 10).

A special type of papillae, which — as far as I am aware — is described here for the first time, is what I propose to call **«papillae calici-penicilliformes»**. These occur in abundance in the middle third of the



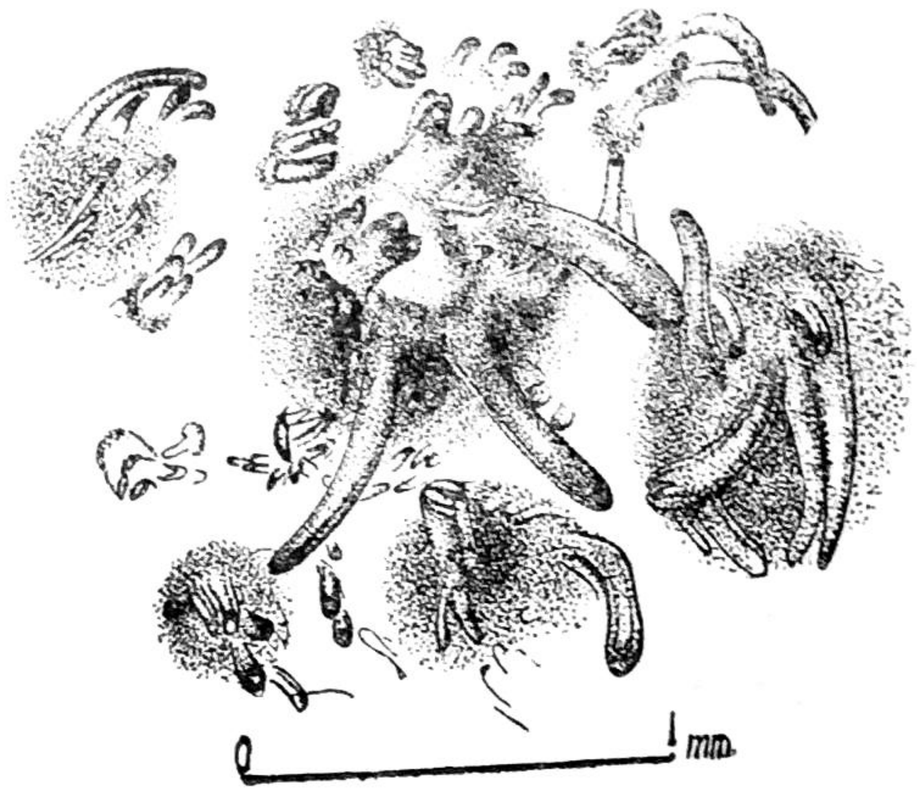
Text-fig. 10 : Part of the anterior third of the dorsum of the tongue, showing different kind, of papillae.

dorsum (Text - figs. 11 and 12), where they are the most conspicuous papillae. In other parts of the dorsum they are scarce, and especially in the anterior third where they are scarcest or almost absent. These papillae may be looked upon as a modified form of the **papillae caliciformes** or **circumvallatae.** They similarly lie in a small depression or fossa but without the characteristic raised ridge or vallus. They are compound; in place of a single papilla in each fossa, there is a bunch of about a dozen papillae. These are long and digitiform and arranged in a circle inside the brim of the fossa. One or two also digitiform papillae may be



Text-fig. 11 : Part of the middle of the dorsum of the tongue, in greater enlargement to show the calici-penicilliform papillae.

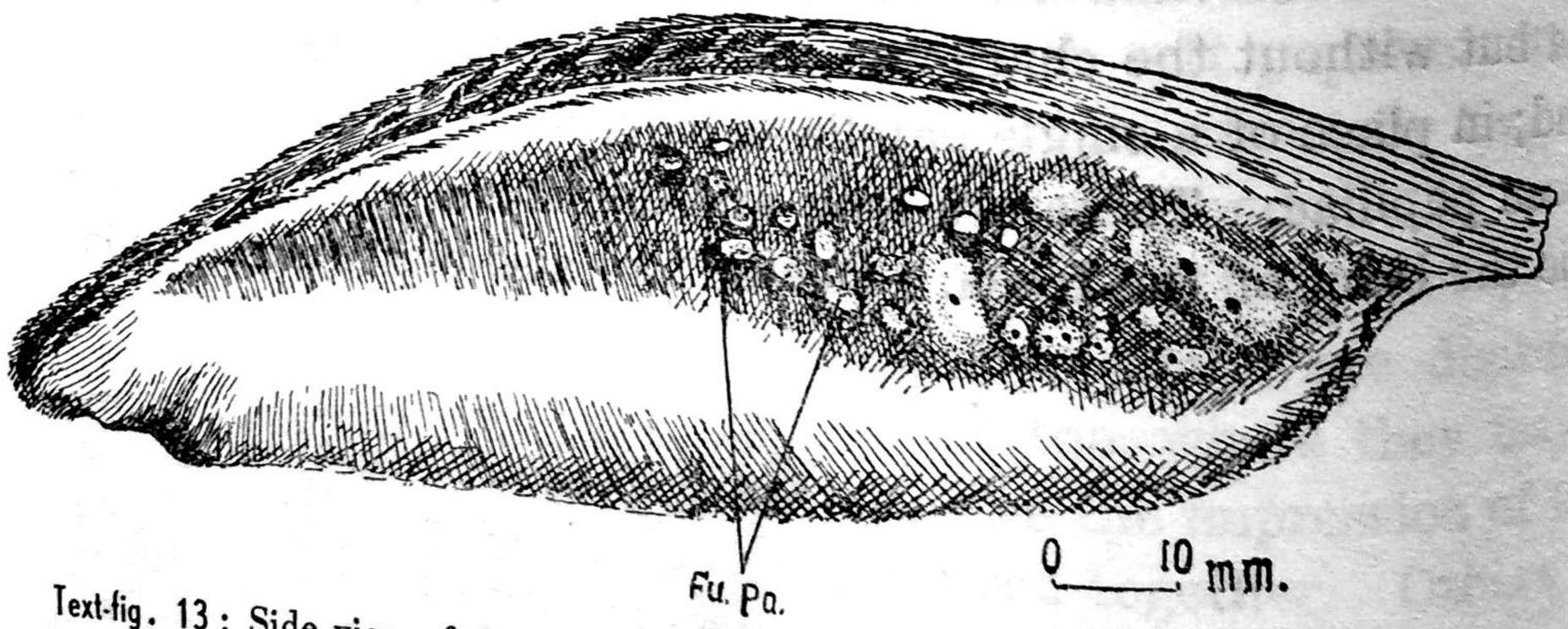
present in the centre of the fossa. In some cases, the bunch of papillae comes out from a common stem, indicating its probable origin from a single papilla with a branched top.



Text-fig. 12: Calici-penicilliform papillae, more highly magnified.

Among the calici-penicilliform papillae are scarttered ordinary digitiform papillae in relatively sparse numbers. No typical circumvallate papillae could be seen.

As described by Hill (1945, p. 159) some dozen deep pits, like pin-holes occur on each side of the tongue, at the middle of its length, a little nearer the upper surface. Only about half of these pits have no



Text-fig. 13: Side view of the tongue, showing the fungiform papillae (Fu. Pa.) and the pin-hole like openings of the glands.

surface projections, in agreement with Hills' description; but the other half lie each in the middle of a low cushion - like elevation. Immediately anterior to these are some 15-20 low fungiform papillae of various sizes and outline, and irregularly arranged, but they are generally low, flat-topped and with somewhat fringed margins (Text - Fig. 13).

Besides the papillae described above, the thick stratified epithelium of the tongue conceals innumerable microscopic papillae which are densely packed all over the surface of the tongue, between the larger

papillae as well as on the sides of the tongue and on the smooth strip on the lower surface, behind the bristly tip. These concealed papillae come in evidence after the pealing off of the lingual epithelium, which readily peals away in preserved specimens. The papillae thus exposed look superficially like feather germs. On the lateral surface of the posterior half of the tongue, these papillae show, on the external epithelium, as minute somewhat hemispherical elevations, which can be seen with the aid of a strong magnifying glass. They lie close to one another, arranged in straight, oblique and parallel lines, close to one another. Removal of the epithelium also discloses that the dermal papillae are of the attenuated type.

Under the startified epithelium lies the corium which is a fairly thin layer of more or less loose texture, and below this is a thick layer, about 1 cm. high, of glandular tissue. This is formed mostly of mucilaginous glands, and is permeated with a small proportion of muscle bundles, and fibrès running in various directions. The mucilaginous glands open into capacious ducts, running in between the glandular elongated lobes, to open on the surface of the tongue, between the papillae. These glands are present under the whole surface of the tongue except the anterior tip, which is covered by the horny layer. In between the mucilginous glands are fewer and smaller serous glands which do not sink into the tissues of the tongue as deep as do the mucilaginous, and are therefore more superficial in position. They are also more distinctly lobulated than the mucilaginous glands. Most of the lobules are purely serous, but in a few points congregations of mucous acini are present among them. These mucous acini often have groups of serous-secreting cells comparable to the cresents of Gianuzzi, as in the case of the human sublingual salivary gland, but here the proportion of the mucous acini is smaller than in the human sublingual gland. The acini in the mucilaginous glands never have the serous-secreting crescents of Gianuzzi.

The rest of the substance of the tongue is formed as usual of cross-striated muscular tissue running longitudinally, transversely and in various directions. The musculature of the tongue is comparatively weak, as is expected in view of its weak mobility.

In fact the structure of the tongue in the dugong is very interesting and calls for further investigation especially histologically and histochemically with a view to elucidate the function of the different types of papillae and their innervation, as well as the structure, distribution and rôle of the glands. I hope I shall be able to devote to it some more time in a later occasion.

THE GENATALIA.

The only difference that distinguishes externally between the males and females, at all ages, is the position of the external genitalia. The upper incisor tusks protrude in males, and the mammary glands are well-developed in females, but none of these characteristics is developed before maturity. On the other hand, males are immediately distinguishable by having on the median line of the belly two widely separated orifices, the anal opening near the root of the tail and the preputial orifice roughly midway between the anus and the umbilicus. In contradistinction, females have the anal opening and vulval cleft so close to one another and moreover possess so well-developed a perineal sulcus that the two openings appear as a single long slit.

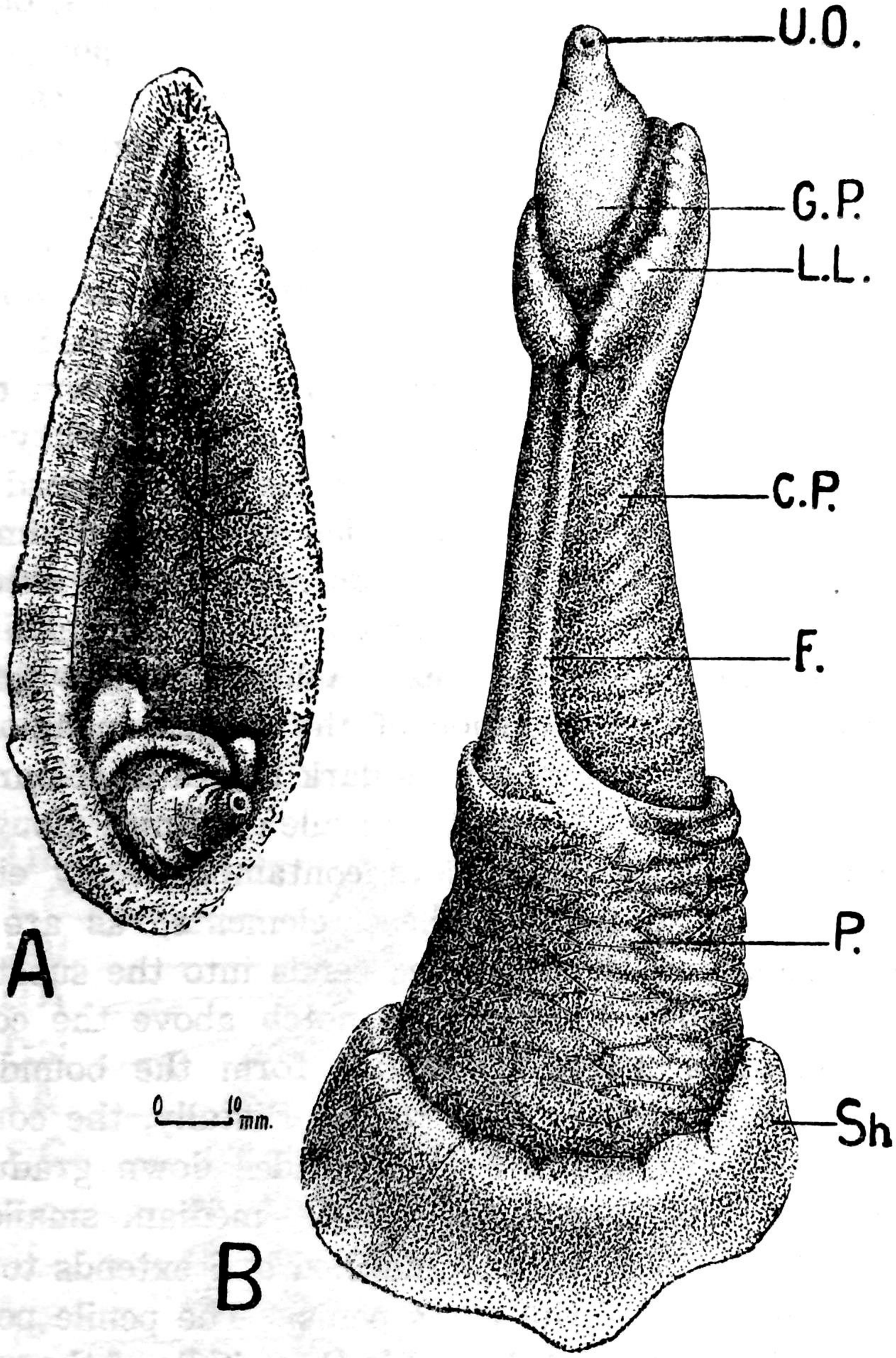
The Male Genitalia (Text - figs. 14, 15 and Pl. II figs. 4 and 5):

In the male, the penis, when at rest, does not show externally as it lies completely hidden in a special perputial chamber which opens to the outside by an independent slit, somewhat nearer to the umbilicus than to the anal opening (Pl. II figs. 4 and 5). The distance between the anal and preputial openings is approximately 1/7th. the total length of the animal.

In the resting condition, the preputial opening is lengthwise elongate, but tightly closed and have labia with somewhat puckered edges, which give the orifice the appearance of a vulval cleft. In the fully developed male, the preputial orifice was about 13 cms. long. The skin surrounding this orifice is smoother, paler and slightly thinner than that of the abdomen in general, but there is no special development of hair in this area. The orifice opens and becomes rather rounded during erection of the penis (Text - fig. 14).

When the labia of the preputial orifice are pulled outwards, the penis appears small and completely concealed, being shrunken, with only the glans lying at the posterior corner of the preputial chamber, leaving the rest of the chamber empty. When erected, however, the penis is found to be fairly long (about 22 cms. in the adult male of 282 cms. total length). It is peg-like and extends ventrally with some inclination (about 30°) cranially. It is roughly circular in transverse section, but except for its distal quarter, the free portion has the dorso-anterior surface slightly prominent showing the relief of the region of the tendons, or the common tendon, of the retractores penis muscles. The diameter of the penis is greater at the base, where it may be about 6 cms., and

narrows down gradually towards the tip, the narrowest point being just before the glans, where the diameter is about 2 cms. (Text - fig. 14 A). The penis then slightly thickens out again to form the **glans penis.** This is a pear-shaped organ, composed mainly of a special erectile tissue, and ending in a short process, the « **processus urethralis** » at the tip of which the urogenital urethra opens. At the base, the glans penis is provided



Text-fig. 14 : Male external genitalia of the dugong. A. preputial sinus with penis retracted ; B. erected penis ; C. P., corpus penis ; F., frenulum penis ; G. P , glans penis; L. L., semilunar lateral lobes, P., penis; Sh., Sheath; U. O., wrethral orifice.

with a collar-like structure composed of two large and prominent semi-lunar lobes, these lie one on each side, and are separated on the ventro-posterior surface. The basal part of the penis is surrounded by the sleeve-like preputial fold and a distinct **frenulum preputiae** extends, on the ventro-posterior surface of the penis, from the preputial fold to the space between the lobes of the glans. The penis is telescoped into the prepuce and the whole thing is, in its turn, telescoped into a sheath

which is continuous with the lining of the preputial cavity. Between the preputial orifice and the anus runs a very faint median sulcus-like depressed line representing the « **raphe** ».

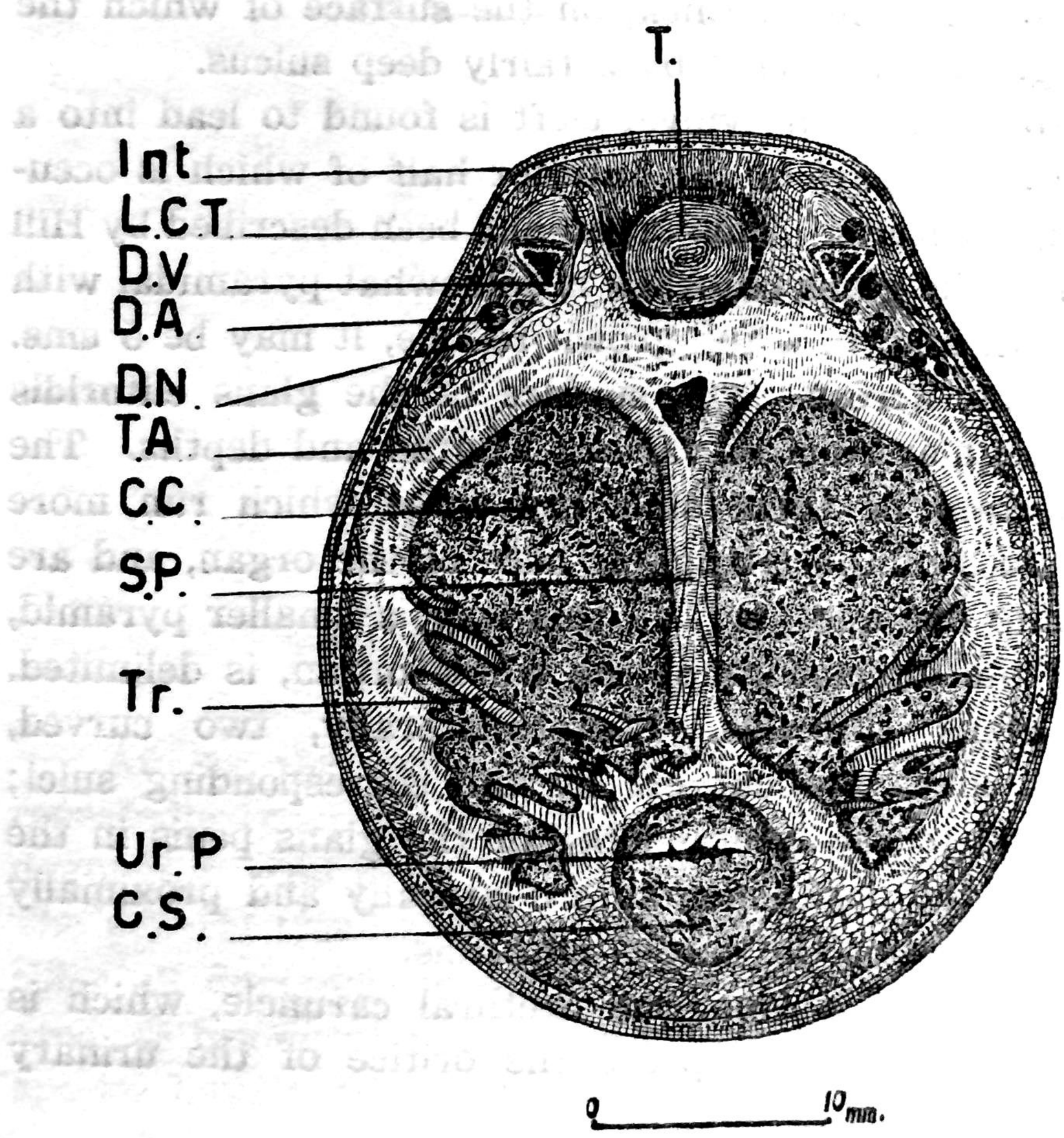
In transverse section the penis is seen as stated by Hill (loc. cit. p. 168) to have « very similar structure to that of the human organ ». The erectile tissues form the majority of its mass and they are similarly composed of two massive and well-developed **corpora cavernosa,** one on each side, and inferior to them is the single median **corpus spongiosum,** in the centre of which the penile portion of the urethra passes. The **corpora cavernosa** are represented by two strong and stout cords of erectile tissue which arise at the root of the organ from the two **crura penis** which converge from both sides. The proximal ends of the **corpora cavernosa** as well as the two crura are surrounded by thick muscles which are very probably the **compressores crurium,** as Hill called them. Except in the distal half of the penis, the **corpora cavernosa** are quite circular in cross section, and about 20 mms. in diameter. As they converge and come next to one another, the facing sides are flattened and remain separated by only the **septum penis,** which is thick proximally, thinning out gradually distally. The corpora decrease very gradually in diameter distally to terminate in an attenuated end, in the middle of the **glans penis**, about 26 mms. before its apex. A broad shallow groove is present ventrally for the partial inclusion of the corpus spongiosum. The erectile tissue of the corpus cavernosum is dark brown in colour and surrounded by a very strong, thick and white capsule or tunica albuginea formed of fibrous and plain muscular tissues containing many elastic fibres. The septum penis is formed of these elements, as are the numerous septa or trabeculae which the tunica sends into the substance of the corpus cavernosum, especially near the notch above the corpus spongiosum (Text - fig. 13). These trabeculae form the boundaries of the erectile tissue and carry the arteries to it. Distally, the corpora cavernosa decrease in thickness and the colour fades down gradually.

The corpus spongiosum is, in contrast, single, median, smaller in cross section, paler in colour, not so sharply defined and extends to only a trifling distance from the apex of the glans penis. The penile portion of the urethra runs along the entire length, and in the middle of the corpus spongiosum. The urethral wall is thick and possesses a well-developed mucous membrane, and in the resting condition the wall is compressed dorso-ventrally, and the lumen is reduced to a narrow horizontal cleft with vertical side-clefts and a fine open canal in the middle. In the distal portion of the urethra the lumen widens out slightly to form the «**fossa navicularis** », which is about 14 mms. long, and has a slightly longitudinally folded wall, and opens to the exterior by the « **meatus urinarius** ».

From the dorsal wall of the **fossa navicularis,** at its junction with the urethra, hangs a small valve-like flap of the mucuous membrane. This flap is « Guérin's valvule » as met with in the human urethra, and apparently serves to close the urethra from the open sinus of the **fossa navicularis.**

The erectile components of the penis, collectively surrounded by the tunica albuginea, constitute the main bulk of the free portion of the penis which is roughly circular in transverse section giving the penis its typical form. On the dorsal side, however, there is a somewhat distinct elevated part, in the middle of which is located the common tendon of the two retractores penis muscles. This tendon runs on the dorsum of the penis for about 9 cms. before the glans penis. It ends abruptly just behind the glans in a thin terminal portion, fixed to the dorsal edge of the proximal end of the glans. The tendon lies in a groove, of corresponding shape and size, in the fascia, but it is not attached to it neither ventrally nor laterally. On the other hand the tendon is attached dorsally, throughout its entire length, to the loose cellular layer of prolapse, below the integument.

The blood vessels and nerves of the penis are all paired and collected together in two bundles, one on either side of the elevation on the dorsum on the dorso-lateral corners (Text - fig 15). In place of the median



Text-fig. 15 : Transverse section of penis. C.C., corpus cavernosum ; C.S., corpus spongiosum ; D.A., dorsal artery; D.N., dorsal nerve; D.V., d rsal vein; L.C.T., loose connective tissue ; S. P., septum penis; T., common tendon of retractores penis ; T.A , tunica albuginea ; Tr., trabeculae ; U. P., urethra penis.

superfical dorsal vein and the profundus dorsal vein of the human penis, there are two lateral dorsal veins of considerable size one in each bundle. Next to the vein is the dorsal artery of the penis, which is comparatively small in size but particularly strong-walled, and sends out a number of branches. In the bundle are also to be seen two or three or more branches of the dorsal penis nerves. There is no cavernous artery, in the middle of the corpora cavernosa, as that found in the human organ.

The penis is externally covered by a layer of delicate and thin skin attached to the underlying tissues by a layer of loose areolar connective tissue, which allows the free gliding of the organ during coitus.

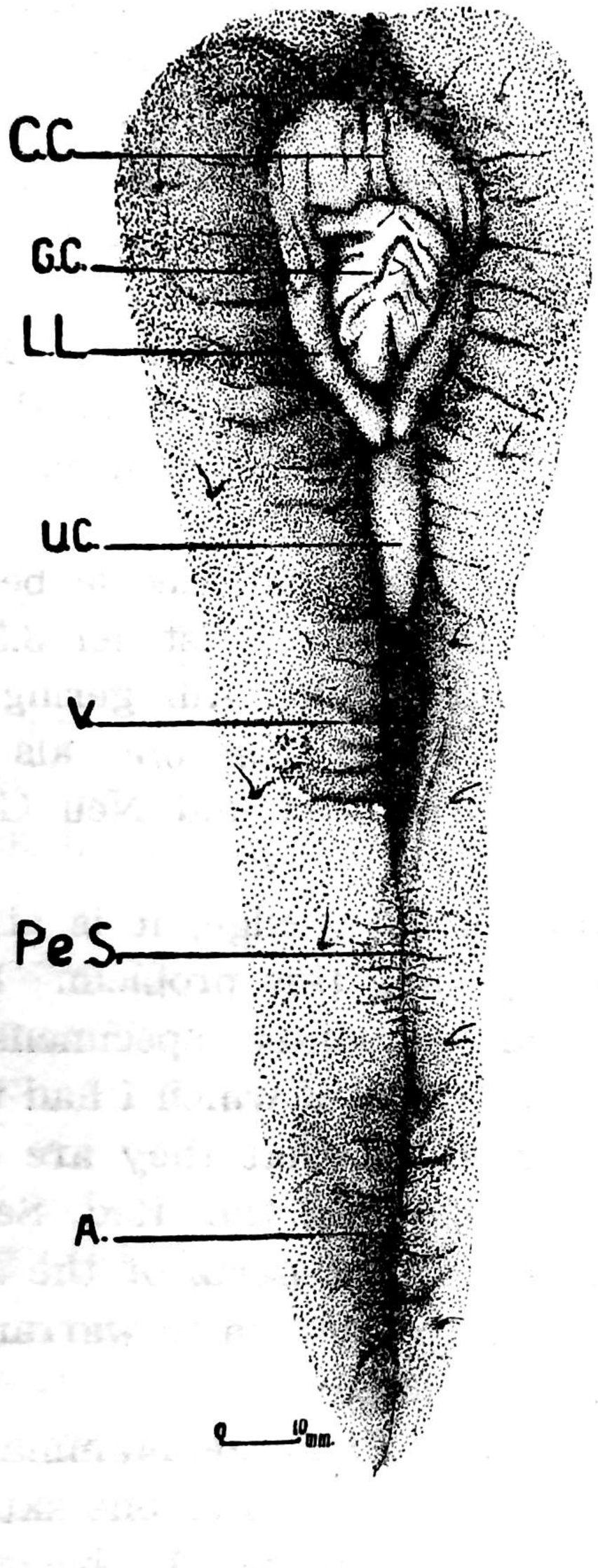
The Female Genitalia (Text - fig. 16 and Pl. III figs. 1 and 3) :

In the female, there appears, along the mid-ventral line in the region of the anus, a single but long cleft (15-20 cms. long in the adult), which has thick and fleshy but puckered labia. The cleft is often seen slightly open at the two ends with a constriction at about one third its length, where the labia approach one another or may touch (Text - fig. 16 and pl. III figs. 1 and 3). Examination of this cleft shows that it is composed of two independent clefts, the vulval cleft, in front, 8 to 10 cms. long, and the anal cleft, behind, 4-6 cms. long, the two openings being separated by a perineum 25-35 mms. thick, on the surface of which the vulval and anal openings are connected by a fairly deep sulcus.

On drawing the labia apart, the vulval cleft is found to lead into a spaceous vestibule, the major part of the anterior half of which is occupied by the much enlarged clitoris. This organ has been described by Hill (1945 pp. 157 and 170). The **glans clitoridis** is somewhat pyramidal with a roughly triangular base, and, in a full-grown female, it may be 5 cms. cranio-caudally and 3 cms. across. The surface of the **glans clitoridis** is thoroughly cut by irregular sulci of various lengths and depths. The largest and most important of these sulci are three which run more or less parallel to the sides of the triangular base of the organ, and are somewhat continuous into one another. In this way, a smaller pyramid, a little more than half the dimensions of the whole organ, is delimited. This represents the **glans clitoridis.** Postero-laterally, two curved, roughly crescent-shaped lobes are cut off by the corresponding sulci; and these may correspond to the lateral lobes of the glans penis in the male. The main bulk of the organ lies antero-laterally and proximally to the glans clitoridis, and forms the **corpus clitoridis.**

Posterior to the clitoris is a lobe, the urethral caruncle, which is elongated cranio-caudally and superimposes the orifice of the urinary **meatus.**

The vagina opens posterior to the urethral caruncle by a fairly large and long, somewhat oval opening, behind which is the thin and low semilunar mucous fold, rightly described by Hill as «resembling the fourchette of human anatomy ».



Text-fig. 16 : Female external genitalia of the dugong. A., anus ; C.C. corpus clitoridis ; G. C., glans clitoridis ; L.L., Lateral lobe of clitoris ; Pe. S., perineal sulcus ; U. C., urethral caruncle; V., vagina.

THE SPECIES OF THE RED SEA DUGONG

Among the first problems that comfront us here is one that has repeatedly cropped out. Namely : are there more than one species of dugongs ? And if so, to what species does the Red Sea dugong belong ?. The general trend and especially of the more modern authors is to consider all dugongs, existing in the various parts of the Indo-Australian area, as belonging to one species, in spite of the fact that at least three species have been described.

Thus, Annandale (1905, p. 239), from the examination of skulls of Indian and Australian dugongs, concluded that « at present I feel confident in stating (with four fully adult Indian, two fully Australian, and parts of three immature Indian skulls before me) that the individual variations among Indian specimens are at least as great as those which were believed by Owen to constitute a specific difference between Indian and Australian species. Skeletons of the Dugong exhibit very great differences (not solely connected with sex and age) inter se and these cannot be specific, as they are not constant even in a series from the same seas. Owen's *Halicore australis*, therefore, must be relegated, as most recent mammalogists have thought probable, to the synonomy of *H. dugung*.

Beddard (1923, p. 337), in Cambridge Natural History, wrote « *Halicore*, the dugong is an entirely Oriental and Australian form; there appears to be but a single species, though more than one name has been given to supposed distinct species ».

Weber (1928, p. 495), however, could not decide between the two views thus stating that « Die bekannteste Art ist der 3.50 m. lange *H. dugung* Erxleben am den Küsten des Indik. Auf geringe Unterschiede hin hat man die in Rothen Meer lebende *Halicore* als *H. hemprichii* Ehrenb. und die an die Küsten Australiens und Neu Guineas lebende als *H. australe* Owen abgetrennt »).

In fact, in our present state of knowledge, it is still not easy to come to a definite conclusion regarding this problem. Descriptions so far available are not complete, and mounted specimens now kept in European museums including types - most of which I had the opportunity to examine - have so much deteriorated that they are not much help either. However, the differences between the Red Sea dugong and available descriptions of Dugongs in other parts of the Indo-Australian region — as shown below — seem to be enough to warrant the retention of the Red Sea dugong in a distinct category.

In 1828, Ehrenberg in his Symbolae Physicae, Mammalia II, established the species *Halicore hemprichii* on the basis of one skull from Barkan Island and also a second species *H. lottum* on the basis of some teeth from Hanakel Island. He simply gave the following diagnoses for his two species :

H. hemprichii E. Nake. Dentibus incisivis conicis superoribus longioribus basi parum excavatis.

« *H. lottvm* (Dugong III.?) Dentibus incisivis conicis superoribus brevioribus, basi profundius excavatis durioribus.

Ehrenberg's diagnoses are, naturally, insufficient and he did not give reasonable descriptions which may help to identify the species. Besides, the differences given in his diagnoses are obvlously far from

being sufficient for a separation between two species, and the characters he gave for the skull and teeth are not specific. Therefore, none of Ehrenberg's two names can be accepted.

The first and only satisfactory description of the Red Sea dugong is that given by Rüppell in 1833 which he tentatively called *Hallicore tabernaculi* on the chance of it proving to be a distinct species. It is to be noted that Rüppell described his specimen while he was on the Red Sea coast completely out of contact with libraries and museums.

Distinctive Characters of the Red Sea Dugong :

Thanks to the authorities of the Frankfurt a/M, London and Vienna Natural History Museums, I was enabled to examine the collections of dugong skins and skeletons in their possession. In the first, was the skin and skeleton of Rüppell's specimen from the Red Sea. The rest of the specimens were all from the Indo-Australian Region with the exception of a female skull and an incomplete skeleton without skull of Red Sea dugongs in the British Museum (Natural History).

From a comparison of that material with mine from the Red Sea, as well as from available descriptions, I am able to point out the following differences that justify the separation of the Red Sea dugong in a special category.

In the first place, there are the differences in size. Thus, whereas the average length of the adult *Dugong dugong* is 3.50 m. (Weber 1928, p. 495), the record for the Red Sea dugong in only 3.15 m. made by Rüppell (1934, p. 104) for a female specimen. My biggest full-grown female which was lactating had a length of 288 Cms. and my full-grown male was only 282 Cms. This male was elderly as can be seen from the characters of the skeleton and tusks.

There also seems to be a very significant difference between the Red Sea and the Indo-Australian dugongs in the size of the young at birth. Thus Turner describing some foeti of *Halicore dugong* mentioned (1894, p. 320) that the largest was 5 ft. 4 in. (162.7 cms.) long. Max Weber (1928, II, pp. 480 and 490) reproduced illustrations of foeti of the same species, studied by Kükenthal, one of which was 162 cms. long. The Red Sea dugong is by far much smaller at birth, as my smallest specimens, which were 120 and 110 cms. long, had passed the lactation period, and were feeding independently. In the 110 cms. long specimen, two molars on each side of the jaw had appeared and their surfaces had already been levelled by attrition through use. The alimentary tract was also full of sea-grasses in the two cases. The Red Sea dugong must, therefore, be less than 100 cms. long at the time of birth.

The mammae also show differences in their character. Annandale (1905, p. 240), describing his male specimen, which measured 290 cms. in length, stated that « The mammae, which were large considering the sex of the individual,..... were long in comparison with their diameter. Judging from a female, otherwise correctly mounted, in the Colombo Museum, this elongated character of the mammae is characteristic of both sexes ». In the Red Sea dugongs, although adult females have elongated mammae of considerable size especially at the time of lactation, the males never have elongated or even prominent mammae. In their places there may be seen circular relatively soft areas covered with thin loose and somewhat wrinkled skin. Adult, non-lactating, females have nipples slightly higher than broad but younger females have rudimentary ones (Pl. II fig. 3).

Differences in the skeleton are numerous. The skull of the Red Sea dugong is generally stronger and heavier and relatively broader. The foramen magnum is slightly larger and the roof of the cranium is distinctly convex in the Red Sea dugong, flat or even slightly depressed in the Australian. The Red Sea dugong has, also conspicuously stronger zygomatic arches and broader and stouter premaxillary bones, in which the angle of curvature is, however, less prominent than in the Australian species. Such differences though slight and somewhat variable, yet taken together they are significant.

In the lower jaw, although abortive teeth are of common occurrence in the deflected portion of the dentary bone where two or three are found (Fernand, 1952, pp. 139 and 140 and Owen 1866 p. 284 etc.) I have never come accross any abortive teeth in my many Red Sea specimens. Nevertheless, I found only one such tooth in the middle right socket in the Red Sea skull present in the British Museum collection. This was smooth, long and rod-like.

If Owen's figure (Owen 1866-68, vol. II, fig. 160, p. 281) is exact we would conclude that, in the Indo-Australian dugong, the deciduous incisor tusk is of a size never attained by its equivalent in the Red Sea dugong. Furthermore, we see that this incisor tusk co-exists with a well-developed permanent tusk inside its socket, whereas in the Red Sea form the deciduous tusk disappears while the permanent one is in a much earlier stage. Owen (1838, p. 42) also stated « In the dry skull I have seen the last molar projecting from its socket before either the deciduous incisor of the first molar had been shed ». In the Red Sea dugong the deciduous incisor as well as the first molar are shed long before the last molar projects from its long socket.

Again the number of sockets in the symphysial part of the lower jaw seems to be constantly four, on either side, in Indian Ocean specimens

(Fernand 1952 and others) but almost one third of the specimens from the Red Sea have four sockets on one side and five on the other.

Of special importance are the pelvic bones as they have shown progressive reduction in the Sirenia, and in the Red Sea dugong the reduction has progressed a little farther and the two remaining bones of the pelvic girdle viz, the ilium and ischium are weaker and more slender than in Indo-Pacific forms.

Further, in *D. dugong* the radius and ulna are fused together near their heads, but in the Red Sea dugong, fusion is greatly retarded, and these bones are always completely free. Fusion is restricted to the thick cartillaginous pad on their surface articulating with the humerus.

In their internal anatomy, it may be mentioned that, after Weber, the length of the intestines is thirteen times that of the body in *D. dugong* (Weber, 1928, II, 491), but it is about 16-17 times the length of the body in the Red Sea dugong.

Hair and spines also show differences, in the details of their form, between the Red Sea dugong and that from Ceylon as mentioned above. Besides, many other differences can be ennumerated, whether in the soft parts, the skeletons or the relative dimensions of the different parts and organs.

But, as mentioned by some authors, in the vast Indo-Australian region, individuals taken from one locality may show differences between themselves as great as, or even greater than, those between individuals from different and remote localities. Such differences cannot, therefore, be taken as specific, and the animals in that vast area may, thus, all be safely relegated to one species *Dugong dugong* (Erxlb). However, the Red Sea dugong, as we have seen above, stands out alone as distinct from all others. Although the differences may be of the same nature as those existing between individuals from the Indo-Australian region, the magnitude of those differences is not the same; it is much greater between the Red Sea and Indo-Australian dugong, and the separation of the Red Sea dugong in an independent category seems to be well justifiable. Nevertheless, these differences do not seem to be so great as to separate genetically distinct species, and the Red Sea dugong can, therefore, be considered as only a distinct subspecies and may thus be called *D. dugong tabernculi.* The distribution of the dugong in the Indo-Australian area is so vast as to give scope for differentiation into distinguishable forms, but the distribution is so continuous as to give no opportunity of separation. The Red Sea, on the other hand, is to a great extent secluded, and conditions in it are so peculiar as to enhance the evolution of new forms.

SUSPECIES

DUGONG DUGONG TABERNACULI

Diagnosis :

Dugongs of smaller average size, adult generally averaging three metres long, young at birth relatively very small, not exceeding one metre in length; Alimentary tract 15-17 times as long as body; conspicuous mammae found only in females, not in males ! skull stronger, heavier and broader, roof of cranium rather convex; zygomatic arch stronger; premaxillaries broader and stouter with less prominent angle of deflection than in the Indo-Australian *Dugong augong*; deciduous incisor as well as first molar shed before last molar projects from its bony socket. Hair roots not swollen into funnels.

The following table (p. 41) summarizes some of the data obtained from specimens of the Red Sea dugong we caught at our Station. They serve to illustrate the differences existing in the relative dimensions of the different parts of the body, as compared with the corresponding measurements, obtained from dugongs of the Indo-Australian region, as available in the literature (Table No. 1).

HABITAT AND DISTRIBUTION.

The Red Sea dugong is found, mainly, in shallow bays and lagoons with abundant vegetation of the sea-grass, *Diplanthera uninervis*. It frequents only isolated places, and abandons areas where they might be disturbed by people, boats, large predator animals or intruders of any kind. So far, this subspecies is restricted in its distribution to the Red Sea and extends into its two annexes, the Gulfs of Suez and 'Aqaba. They are extremely rare at the present time, but seem to have been much more abundant a century or more before. Females seem to be commoner, or at least more often caught in the net than males. The great majority of my specimens have been obtained from the bays and lagoons in the west of the Strait of Jubal, and its vicinity, i.e. in the north-western corner of the Red Sea proper and the entrance to the Gulf of Suez.

A putrifying carcasse was obtained from the shore at Ras Gharib, at the middle of the western coast of the Gulf of Suez. The skeleton in the British Museum (Natural History) was obtained from 'Aqaba, but it was, most probably, caught by fishermen not at 'Aqaba itself but

TABLE I

Specimen No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16*
Date of Capture	7 Nov. 1942	4 Feb. 1945	4 Feb. 1945	5 April 1945	5 April 1945	4 July 1948	30 Nov. 1948	17 Mar. 1951	17 Mar 1951	29 Mar. 1951	1 Oct. 1951	4 Nov. 1951	20 Sep. 1952	10 Nov. 1953	8 Mar. 1954	2 Jan. 195G
Sex	♂	♀	♀	♂	♀	♂	♂	♀	♂	♀	♀	♂	♀	♀	♀	♀
Total Length	198	277	225	207	288	208	282	215	192	220	170	195	254	220	220	215
Weight in kgs.	170	280	237	193	430	190	346	170	138	—	—	—	—	—	273	200
Length of Muzzle	—	—	—	13	18	13	—	14	13	13	12	12	20	14	—	11
Breadth of Muzzle	—	—	—	18	27	15	17	19	17	20	17	16	25	18·5	—	19
Length of Chin	9	—	—	—	14	10	—	10·5	10	13	11	11	13	11	—	12·5
Breadth of Chin	8	—	—	—	18	9	—	13	13	20	18	15	23	18	—	20
Length of Flipper	31	—	—	28	45	26	39	28	27	28	22	29	32	29	32	27
Breadth of Flipper	13	—	—	14	20	45	—	15	14	15	13	14	18	15	15	15
Length of Neck	—	—	—	20	28	22	—	—	—	—	—	—	—	—	—	—
Anterior Circumferance of Neck	76	—	—	82	98	76	100	72	63	79	76	72	92	67	—	80
Posterior Circumference of Neck	—	—	—	—	—	116	—	105	88	104	80	90	128	105	—	122
Circumference of Chest	126	—	—	118	166	131	165	150	135	145	118	130	140	135	—	155
Greatest Circumference of Belly	162	—	—	160	217	162	200	167	150	165	140	146	175	180	—	170
Distance between Submental Sulcus & Genital Orifice	90	—	—	—	—	—	—	135	120	152	116	115	—	150	—	148
Length of Genital Orifice	5	—	—	—	—	—	—	7	—	—	4·5	5	—	5	—	5
Length of Anal Opening	—	—	—	—	—	4	—	3·5	2·5	—	3	3	—	3	—	2
Distance Between Genital Orifice & Anus	28	—	—	30	—	31·5	38	4	32	4·5	4	3	—	5	5	3·5
Anterior Circumfercnce of Tail	42	—	—	—	—	—	62	50	35	45	40	45	—	52	—	44
Distance between Anus & Beginning of Tail Fluke	43	—	—	—	—	—	85	45	40	40	50	40	44	—	50	—
Breadth of Tail Fluke	70	83	—	65	90	74	80	59	56	73	51	63	69	71	—	61
Length of Small Intcstines in metres	10·5	15·5	110	11·0	18·5	13	11·7	13·5	12·7	—	—	—	—	—	—	13·6
Circumference of Small Intestines	—	10	—	—	—	11·5	15·8	11	10	—	—	—	—	—	—	10
Length of Large Intestines in metres	17·5	28·0	190	17	33 5	18·8	27	20	20·5	—	—	—	—	—	—	21·3
Circumference of Large Intestines	—	17	—	—	—	18	22	14	13	—	—	—	—	—	—	15
Length of Caecum	—	—	—	30	—	36	—	37	40	—	—	—	—	—	—	30·5

All measurements are in centimetres except where otherwise stated.

* This specimen was obtained after completion of manuscript.

in its vicinity. Rüppell found his specimen at Dahalak island, while Ehrenberg got his skull and teeth from Barkan and Hanakel Islands respectively. Thus, the dugong occurs all over the Red Sea from the southern to the two northern extremities.

As is well known, the dugong is a strictly herbivorous animal, and does not take any sort of animal food. The food of the Red Sea dugong is constituted entirely and solely of the sea-grass *Diplanthera uninervis* (Forsk.) Williams. This is a marine monocotyledonous plant of the family Potamogetonaceae, with long, very narrow leaves, closely related to *Posidonia australis*, which forms the food of the Australian dugong. I have carefully examined the contents of the stomachs of all specimens of dugongs we caught and found that they were always full of that sea-grass, and contained no other sea-weeds or algae of any kind.

The mode of grazing of the dugong is rather peculiar. It seems that it does not take the grass into the mouth directly after uprooting it from the soil, nor does the dugong pasture haphazardly, as do many terrestrial herbivorous animals. The dugong seems to pull out the sea-grass from the sea bed — mainly by the flippers — and gathers them into stack-like heaps. Several such heaps are made at a time, and then the animal starts devouring one heap after another, in more or less regular order. When disturbed, the dugong takes to flight, leaving behind the evidence of its mode of feeding, which betrays its existence in the neighbourhood. The reason for such mode of grazing is not quite clear, but it may be suggested, however, that it may be of value for two purposes : 1) It gives time to the mud and sand stirred during the process of uprooting the sea-grass, to settle, thus minimizing their very injurious effect on the relatively delicate chewing apparatus, composed of the horny plates and the few molar teeth, devoid of enamel, 2) It also gives opportunity to the animals, living among the sea-grass, to creep out of the heaps as such animals are not desired, besides the fact that some of them — such as some fishes, holothurians, molluscs, polychaetes etc. — may actually be injurious or poisonous to the dugong.

Being very shy, dugongs are not easily observed in the sea in their natural environment. Thus, little can, at present, be added to our very sparse knowledge of its biology or behaviour, as since we built our large vivarium for the special purpose of keeping large living specimens for observation, we have not succeeded in procuring one dugong alive, and we will have to wait for the first opportunity of obtaining a living specimen.

WORM PARASITES.

The nematode worm *Paradujardinia halicoris* (Owen) has long been discovered in the Australian dugong, after which it was given the name. These worms were, also, met with in the Red Sea dugong, in some specimens of which they occurred in great abundance. In all cases, these parasites were restricted to the stomach, and never were they met with in other parts of the alimentary tract. Their most preferred site, however, is the glandular annex of the stomach. This is a glandular organ, about the size of a man's fist, lying between the mucosa and the musculosa of the stomach wall, in the left side of its anterior rotundity, and opens into the cavity of the stomach, through an aperture which may be 5-14 mms. in diameter.

When the worms are present in comparatively small numbers, they are usually restricted to the cavities in this gland. The occurrence of these worms in this gland in the Red Sea dugong was also previously recorded by Rüppell (1833, p. 106), in the female dugong he described as follows, « In diesen traubenförmigen Höhlungen (meaning the cavities in the gland) fanden sich viele 5 Zoll lang Entozoen.»

Out of the 15 specimens we have caught in the Red Sea, 8 (53%) were infected with these worms. In most cases, these parasites did not seem to have had any conspicuous effect on their host animals, as may be inferred from the normal appearance of the stomach, as well as from the normal weight of infected individuals as compared with parasite-free ones.

In only a single case, however, a female dugong, 277 Cms. long and 380 Kgs. in weight, was so heavily infected with *P. halicoris* that I obtained as many as 540 worms of this species from the stomach. This organ was, also, so full of them that some worms had part of their length extending into the end of the oesophagus, while others similarly extended into the beginning of the duodenum. The stomach was greatly distended while the glandular annex was naturally swollen with them. Some of these nematodes had pierced, and passed, through the mucosal or glandular and muscular layers of the stomach, to come to lie underneath the serosa especially through the gland where the musculosa is relatively thin and weak (Pl. III fig. 2).

A number of these parasites had even completely pierced through all the layers and passed into the peritoneal cavity. The condition of the dugong host was, evidently, seriously deranged by that heavy infestation, as can be seen from an examination of the affected organs. The gastric mucosa was very badly inflamed throughout its entire surface.

The stomach wall, in an area 14 cms. in diameter, was markedly swollen and congested, and, in some parts, showed ulcerations and other pathological manifestations, especially sloughing of the mucous membrane. On the other side, the peritoneal covering of the stomach and neighbouring parts was also inflamed. It is to be wondered, how this animal lived, and what its fate would have been and whether it would have possibly gotten over this acute condition, and how?. However, besides these pathological manifestations, no other signs of morbidity could be observed, and it may be noted that the body weight was not below the normal.

Another female dugong, which was obtained at the same time from the same spot, as the specimen described above, measured 225 Cms. and weighed 237 Kgs. It had 170 nematode parasites, but showed no pathological signs in the stomach. The next case, in order of number of parasites, was that of also a female, which harboured 102 worms. It measured 215 cms. and weighed only 145 Kgs. This weight was well below the normal, but, otherwise, the dugong showed no recognizable signs of disease.

Less frequent and also much smaller and less conspicuous than *Paradujardinià* are other parasites of the Trematoda. These were encountered only in the caecum, and never in any other part of the alimentary tract. They are peculiar seed-like bodies, of small size measuring 6-17 mms. long, 2-5 mms. broad and 1.5-2.5 mms. thick. They are of light pinkish to creamy colour. They are tough animals, incapable of movement, though possessed of a certain power of contraction and very slow, rather slight curling towards the ventral side.

Contraction begins at the anterior end, and there it is usually greatest, and the worm acquires, at this part, an annular appearance. These worms are very slippery and smooth, the cutricle, being plain and devoid of all kinds of growths such as spines or papillae. They are slightly dorso-ventrally flattened; the dorsal surface being slightly convex while the ventral is rather concave. The lateral margins are roughly parallel, the anterior end is, however, often slightly attenuated but the posterior is blunt and more or less broad. The breadth is usually greater in the middle than at either end and the worm is thus somewhat oval but long.

Characteristic of these parasites is a rudimentary oral sucker lying anterior to, and distinct from, the pharynx. The ventral sucker is also peculiar fòr being superficial, shallow and bordered, posteriorly, by a post-acetabular flap of the cuticle with flat glistening surface.

These worms belong to a family of trematodes, known as Paramphistomatidae Fischoeder. A number of these worms were sent to Dr. I. S. Hilmy, Professor of Parasitology at the Faculty of Medicine of the University of Cairo, for study. He found that they were distinct from, all the known genera of the family Paramphistomatidae and that a new genus *Solenorchis* Hilmy had to be established to receive them (Text - fig. 17). The worms also fell into four species which he called *S. Travassosi, S. Gohari, S. Naguibmahfouzi and S. Baeri,* Hilmy 1949.



Text fig. 17 : *Solenorchis*, ventral and lateral views.

In the character of the excretory system, and of the intestinal caeca, as well as in the absence of Laurers canal, the present genus, *Solenorchis,* differed so widely from all known paramphistomes that a new subfamily Solenorchinae was founded to accomodate this genus.

Only about 25% of the dugongs caught were infected with *Solenorchis,* the heaviest infection consisted of 86 worms. One female dugong caught recently was infected by *Solenorchis,* but besides, it was also infected by another trematode worm from a family other than the Paramphistomatidae. These are slightly longer, broader and thinner than *Solenorchis.* They have been identified by Professor I. S. Hilmy as *Rhabdiopaeus taylori* Johnston, a species which was met with before, only once, in the Australian dugong in 1913. Its discovery in the Red Sea dugong is of interest.

It is noteworthy that all dugongs infected with parasitic worms were females, with the exception of a single male specimen which had *Paradujardinia* only.

SUMMARY

Record is made of 16 specimens of the dugong caught in the Red Sea, and contributions are made to the anatomy and biology of this rare mammal. Flippers dig out and collect together food sea-grasses and help in creeping on the sea-bottom, as well as in holding fast to it. The nipples are developed only in females; they are cone-shaped. The structure of hair and spines is described. The horny plates of the upper and lower jaws are built up on the same plan, although they differ in details of their structure. Behind the upper plate are 16 to 25 claw-like hard horny sturctures of unknown function. The lower plate is a fully developed organ, for the firm fixation and proper functioning of which, the underlying sockets of the abortive incisors have developed in an appropriate manner. A new type of lingual papillae, « the papillae calici-penicilliformes », is described. The morphology of the male and female external genitalia is rendered.

A discussion of the species problem in the dugong concludes by considering the Red Sea dugong as forming a distinct subspecies which is called *Dugong dugong tabernaculi.* It feeds exclusively on *Diplanthera uninervis* The mode of grazing is described.

Red Sea dugongs are often infested by *Paradujardinia halicores* Owen in the stomach, *Solenorchis Travassosi* Hilmy, *S. Gohari* Hilmy, *S. Naguibmafouzi* Hilmy, *S. Baeri* Hilmy and rarely by *Rhabdiopaeus taylori* Johnston in the caccum.

APPENDIX

The Origin of the Legend of Mermaids

The relation between the dugong and the legends of mermaids is still a matter of considerable public interest and fertile speculation. Visitors to our Station usually get curious when they see the mounted skins of dugongs and their skeletons; and think of the far-fetched resemblance to human beings. It may be mentioned, however, that the origin of the legends of mermaids may be sought in the dugongs, rather than in the manatees, seals or the like, which were also considered as the origin by one author or another.

In the dugong, the oval ventral face of the relatively small head, of light colour and roughly the same size as a human face, also the fatty chin and the protruding nose-like alveolus of the upper jaw, lying over a small mouth, all these are characters that enhanced the resemblance

to a human face. The flat ventral surface of the muzzle gives the impression of a woman hanging a veil over her head to below the eyes.

It has also been claimed that the mother has been seen, in shallow water, holding her large-size single young with one or both flippers and standing waist-high out of the water, while suckling the young at its well-developped pectoral breasts. At all events, it is imperative that the mother should, during suckling, maintain her own as well as her offspring's nostrils above the water for aerial respiration. The resemblance to a woman carrying her child has been accentuated by the great shyness of dugongs, which made it impossible to watch them except at a great distance, and often only in the darker nights. At the sight of an approaching object or person, they dived and the appearance of the tail beating the surface of the water aroused the curiosity and served to enliven and perpetuate the sea-man's faith in such mythical creatures.

The stories of mermaids were especially told by voyagers in the south-eastern seas, where only dugongs occurred. Furthermore, it is of special interest to remember, in this connection, that many stories told of marriages taking place between mermaids and men. Marriages, which — the stories often went on to relate — resulted in an offspring that talked the languages of both the father and the mother etc. Although such stories are extremely imaginative, yet they cannot of be passed over without some meditation, as they must have some meaning which may lead us to the clue of the problem we are confronted with. At the same time, due consideration should be given to the following facts : 1) The great resemblance between the genitalia of dugongs and those of man; 2) That dugongs are warm-blooded animals and, on account of their blubber, will retain the high temperature of their bodies for some hours after death, especially in the hot climate of the regions in which they occur; 3) That they are docile and inoffensive creatures; 4) That in old times voyages took very long and men were for months and even years, away from their homes and families, at sea or in places or islands completely devoid of human inhabitants. Considering these facts together, it is not difficult to understand, under such abnormal conditions, how much femininity a thing like a female dugong may suggest and how much the seizure or even the sight of one may mean. It may be remembered that, in this respect, man has not completely raised himself above the rank of animals.

APPENDIX II

At the end of the printing of this paper, came to my attention the chapter written by Professor G. Petit in « Traité de Zoologie », (T. XVII, fasc. 1, 1955, pp. 918-981) on the Sirenia. In that chapter, Professor Petit very ably gave a comprehensive account of our present knowledge of the anatomy and biology of these little known animals. Petit expresses the view that : « Une espèce occupant de si vastes espaces doit constituer des sous-espèces ou races géographiques. Mais chez les dugongs les variations individuelles sont si grandes et le nombre des spécimens examinés pour chaque contrée si restreint, que nous n'estimons pas possible, a l'heure actuelle, de définir ces sous-espèces et leur aire de repartition.» He adds: « Nous pensons que la forme de la Mer Rouge..... est également synonyme de l'espèce indienne ». In the present work, however, distinctive features — some of which are definitely beyond the scope of individual variations — have been observed which are well sufficient to separate the Red Sea dugong in a separate category as a subspecies of the species *Dugong dugong* (Erxleben). Rüppel's specific name for the Red Sea dugong has been chosen for that subspecies.

In the same chapter, Dr. R. Ph. Dolfus (pp. 891-92) writing on the parasites of the dugong, expressed his conviction that the four species of *Solenorchis*, described by I. S. Hilmy (1949) and namely : *S. Travassosi*, *S. Gohari*, *S. naguibmahfousi* and *S. Baeri* are synonymous with what he described as *Zygocotyle* sp. but hesitated to attribute to *Z. lunata* (Diesing). Professor Hilmy, in a private discussion with me on the subject, confirmed his view that the four species were distinct from one another, and that the genus *Solenorchis* was valid. The validity of *Solenorchis* has been evidently recognized by Hilary Cruz (1951), who established a closely related genus, *Indusolenorchis*.

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PLATES

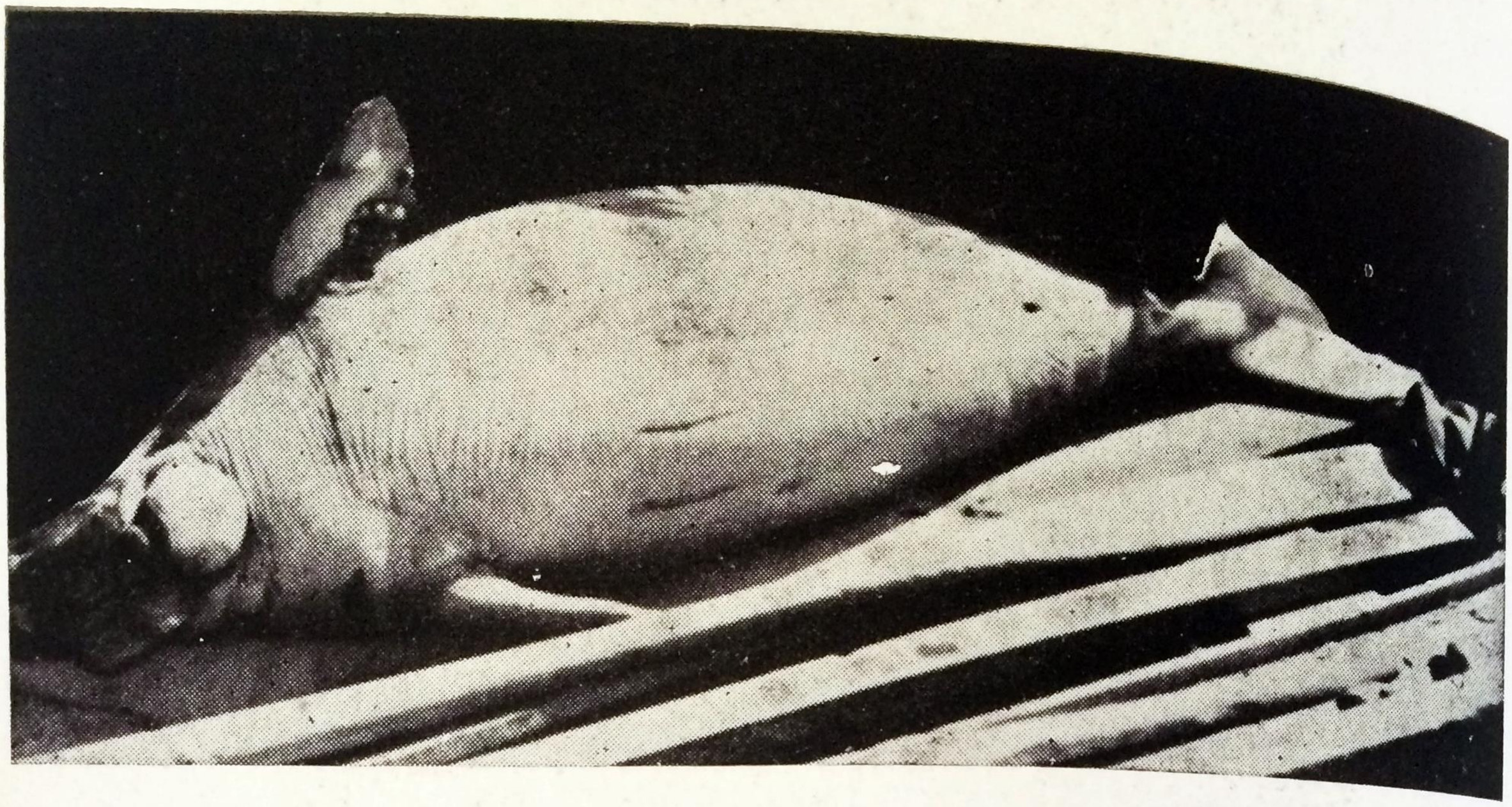


Fig. 1 : Male dugong caught on 7 November 1942 (first specimen caught).



Fig. 2 : Same specimen, abdomen opened to show the large peritoneal cavity and the long transversely coiled intestines, in natural position, obscuring other viscera.



Fig. 3. : Ventral view of anterior half of a female dugong, showing the ventral surface of the muzzle with the sulci, the large fatty chin, the flippers etc.

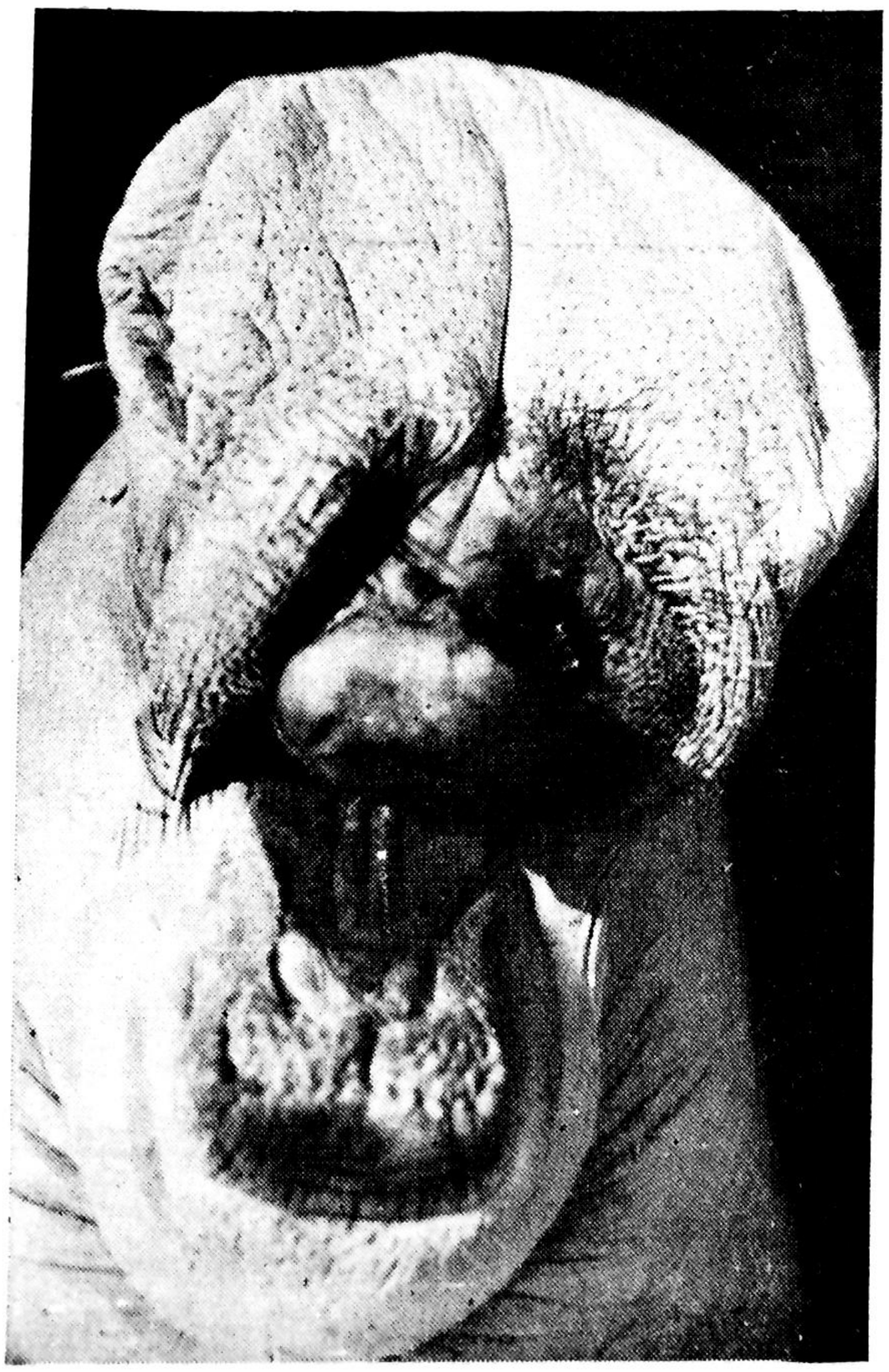


Fig. 4 : Ventral view of head with mouth opened to show lower horny plate, cornified processes in front of it, the bristles round the mouth and all over the rurfaee.

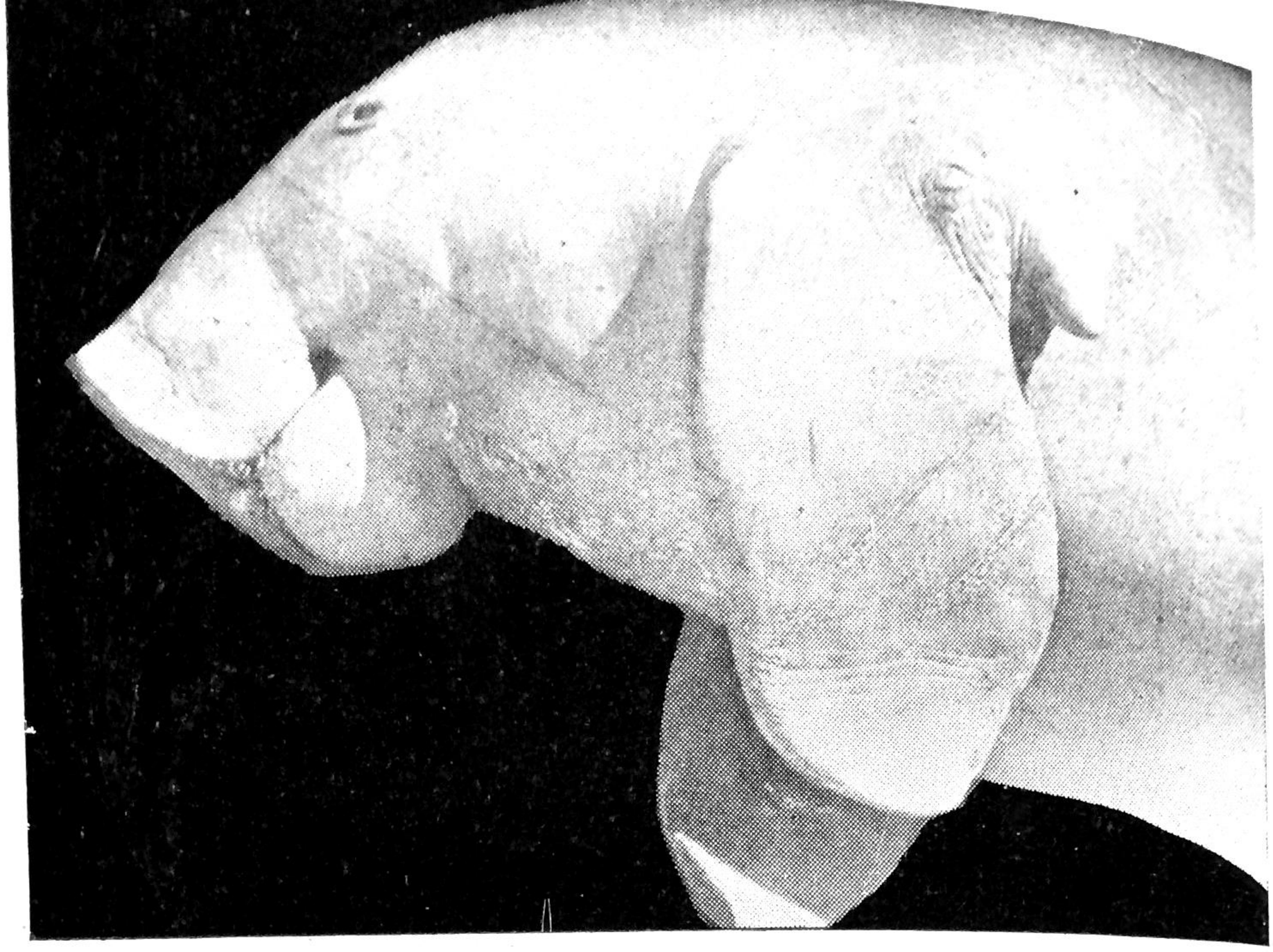


Fig. 1 : Lateral view of anterior part of lactating female dugong showing head with small eyes, flippers and conical nipples in axilla

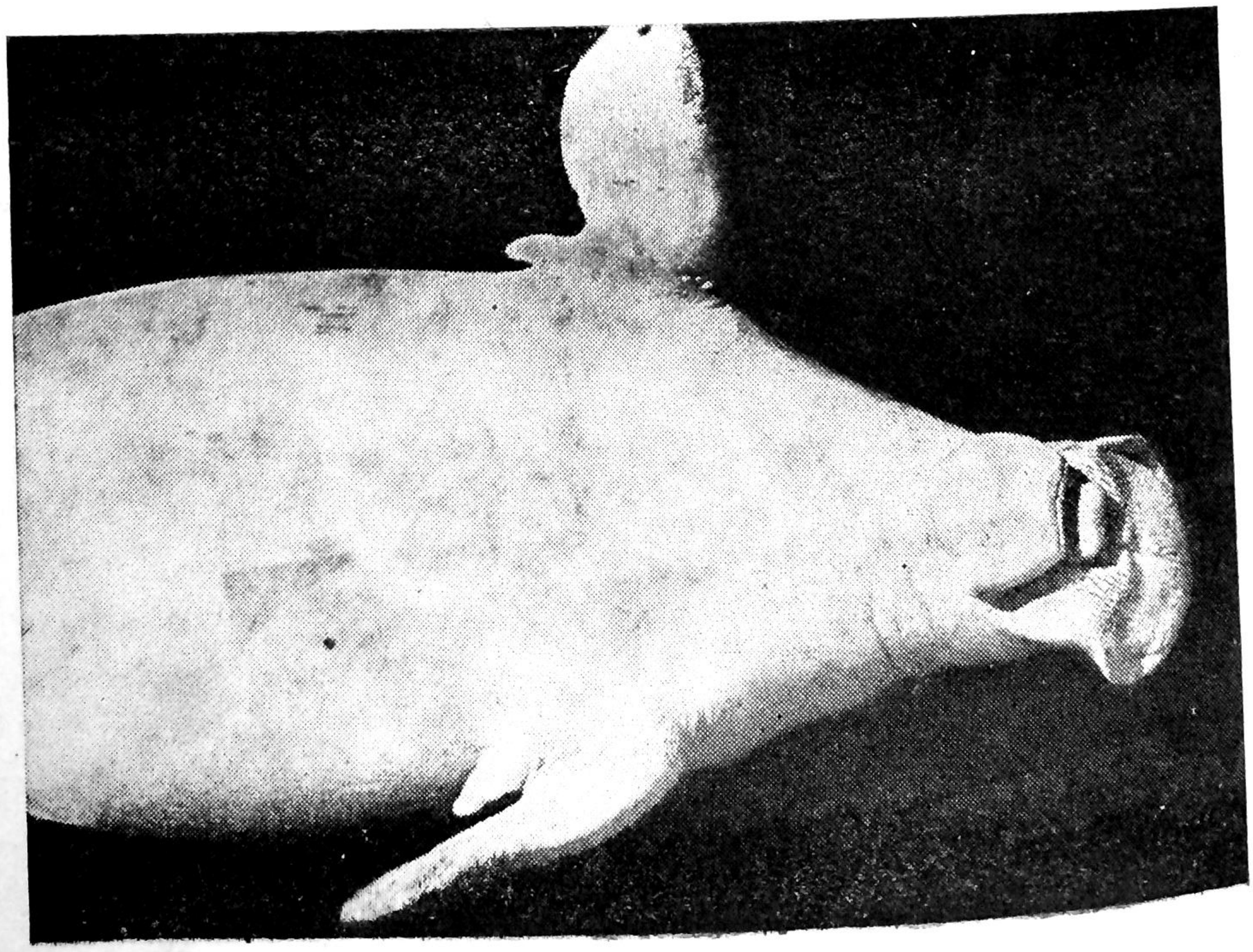


Fig. 2 : Ventral view of anterior part of same lactating dugong showing elongated nipples.

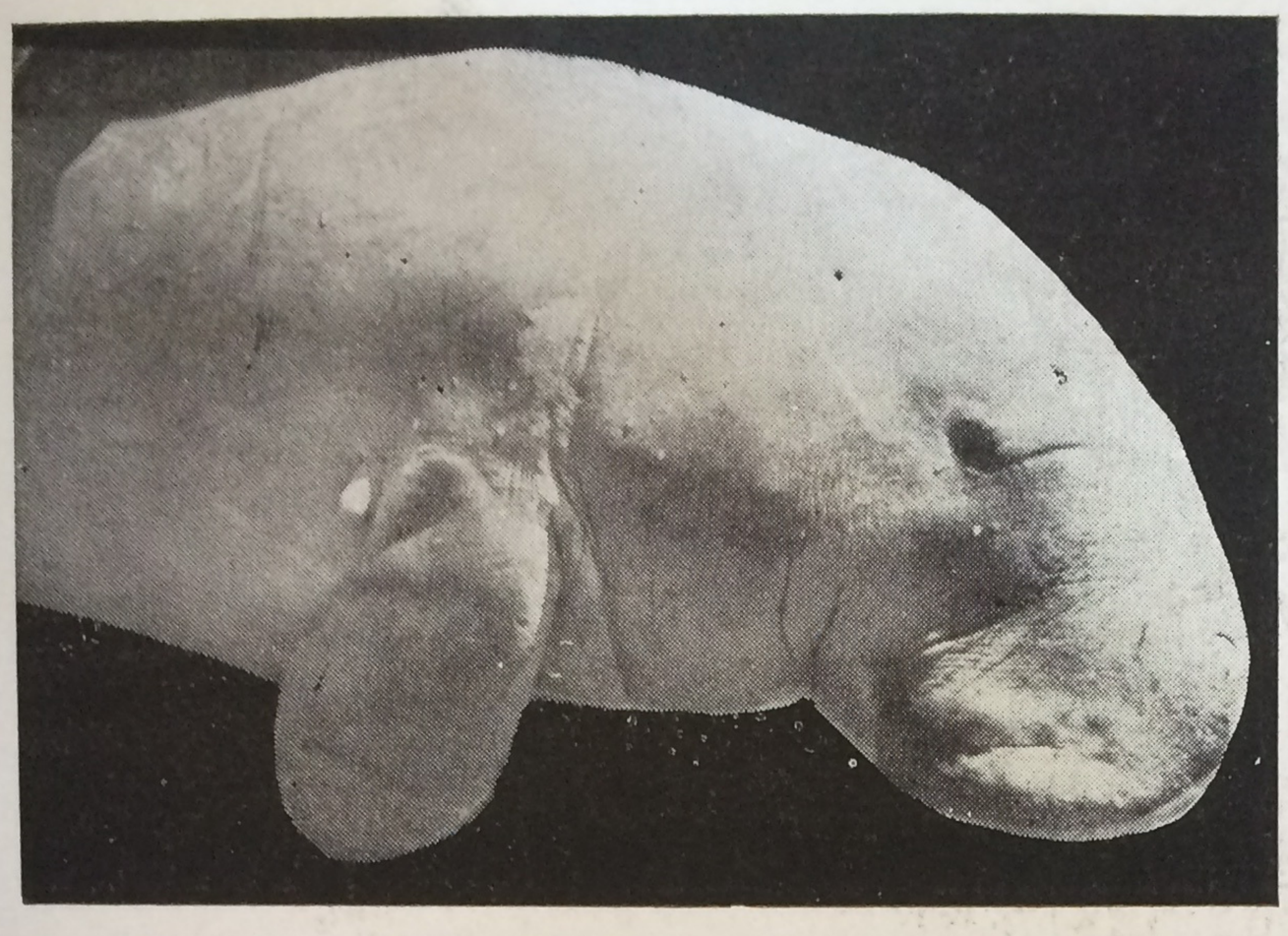


fig. 3 : Lateral view of non - lactating female, showing small nipple, eye, nostril and auditory aperture.

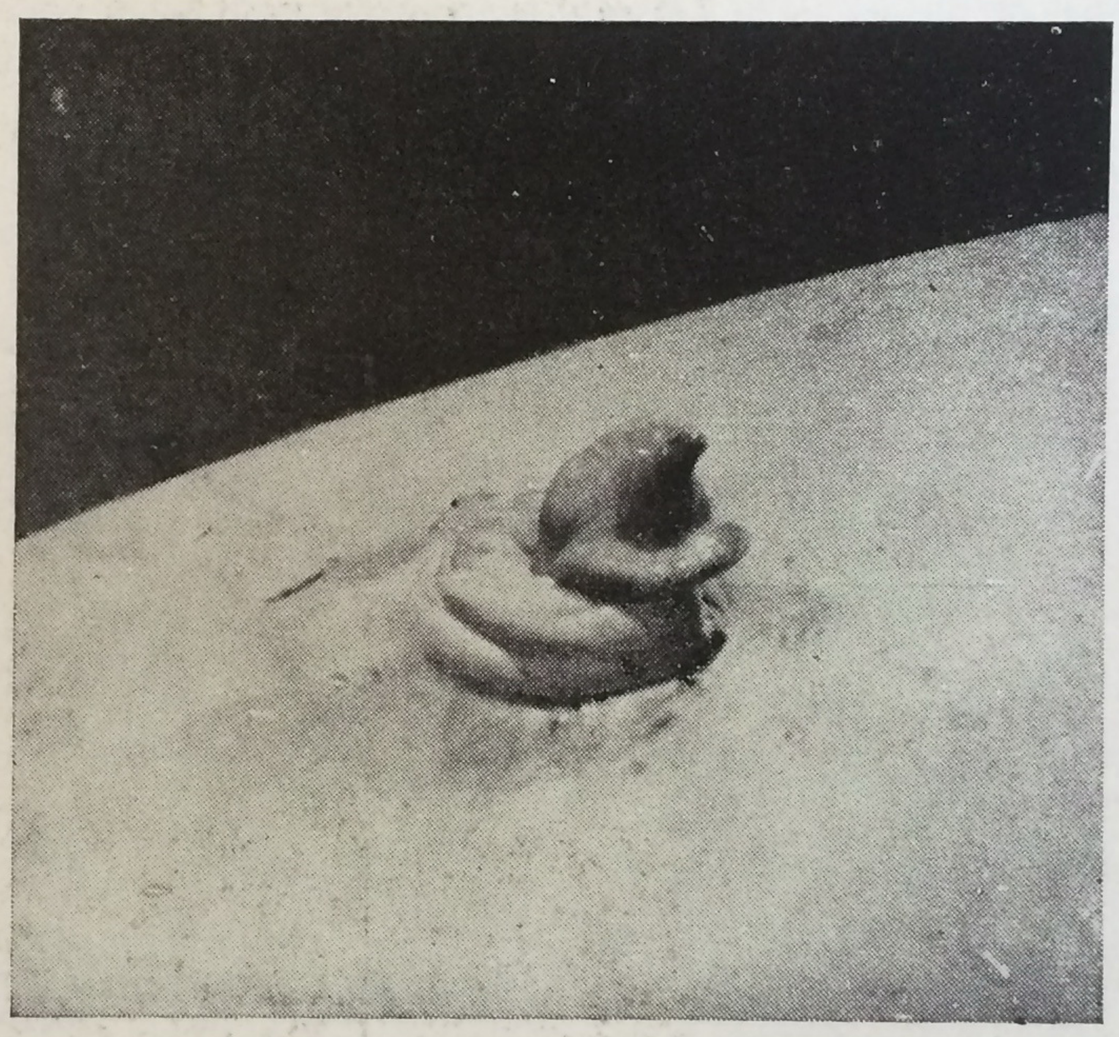


Fig. 4 : Half erected penis

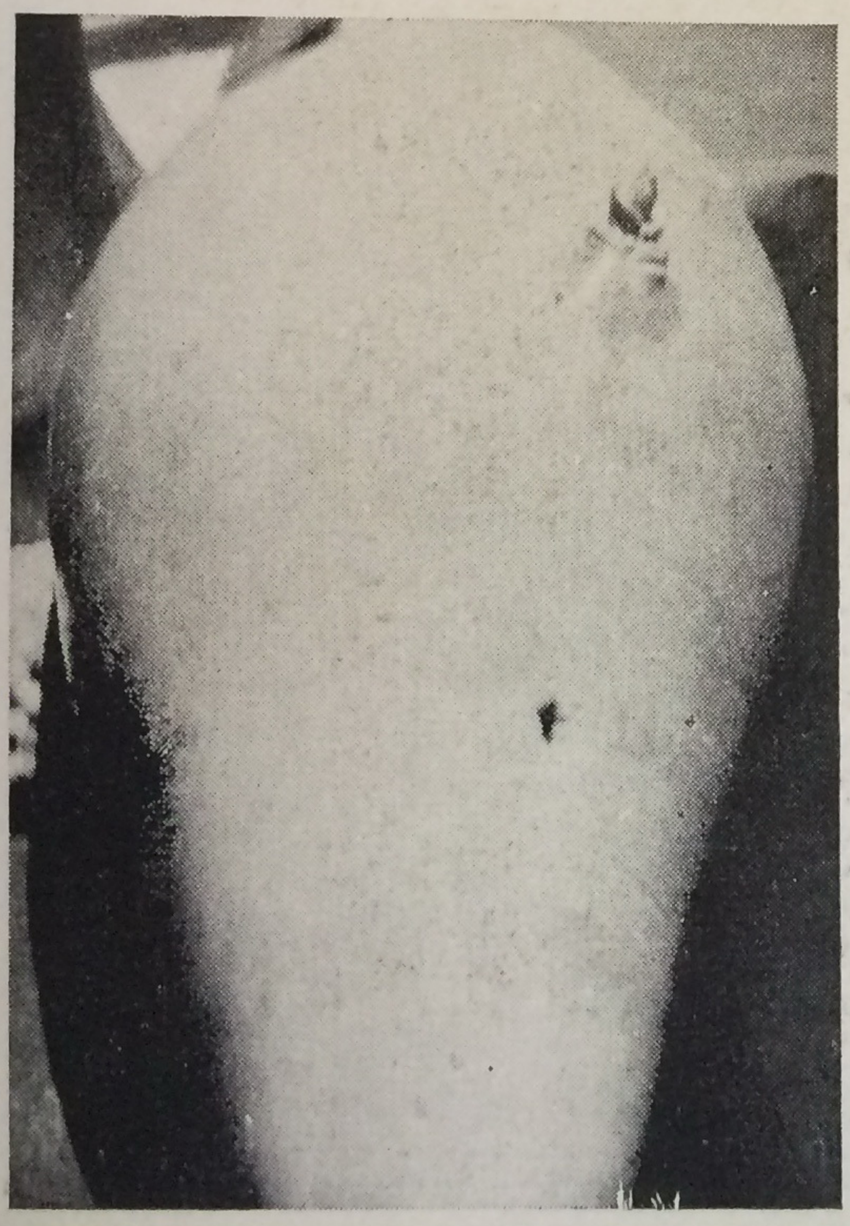


Fig. 5 : Male showing anus and half-erected penis.

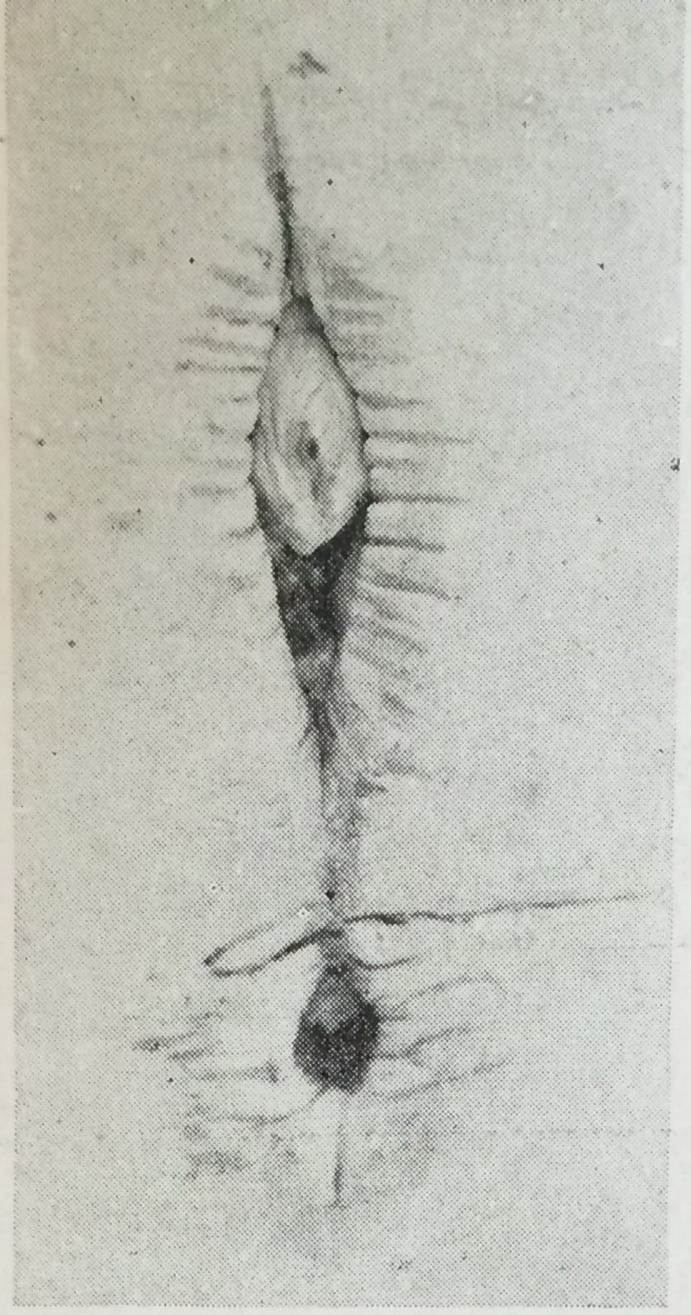


Fig. 1 : Anus and female genital aperture, slightly opened to show clitoris.



Fig. 2 : Stomach, showing holes (a) caused by escape of *Paradujardinia halicores;* the worms (b) still lying under the serosa. Duodenal caeca can be seen while the large ordinary caecum (Ca) has been brought forward to come into the picture behind the stomach.

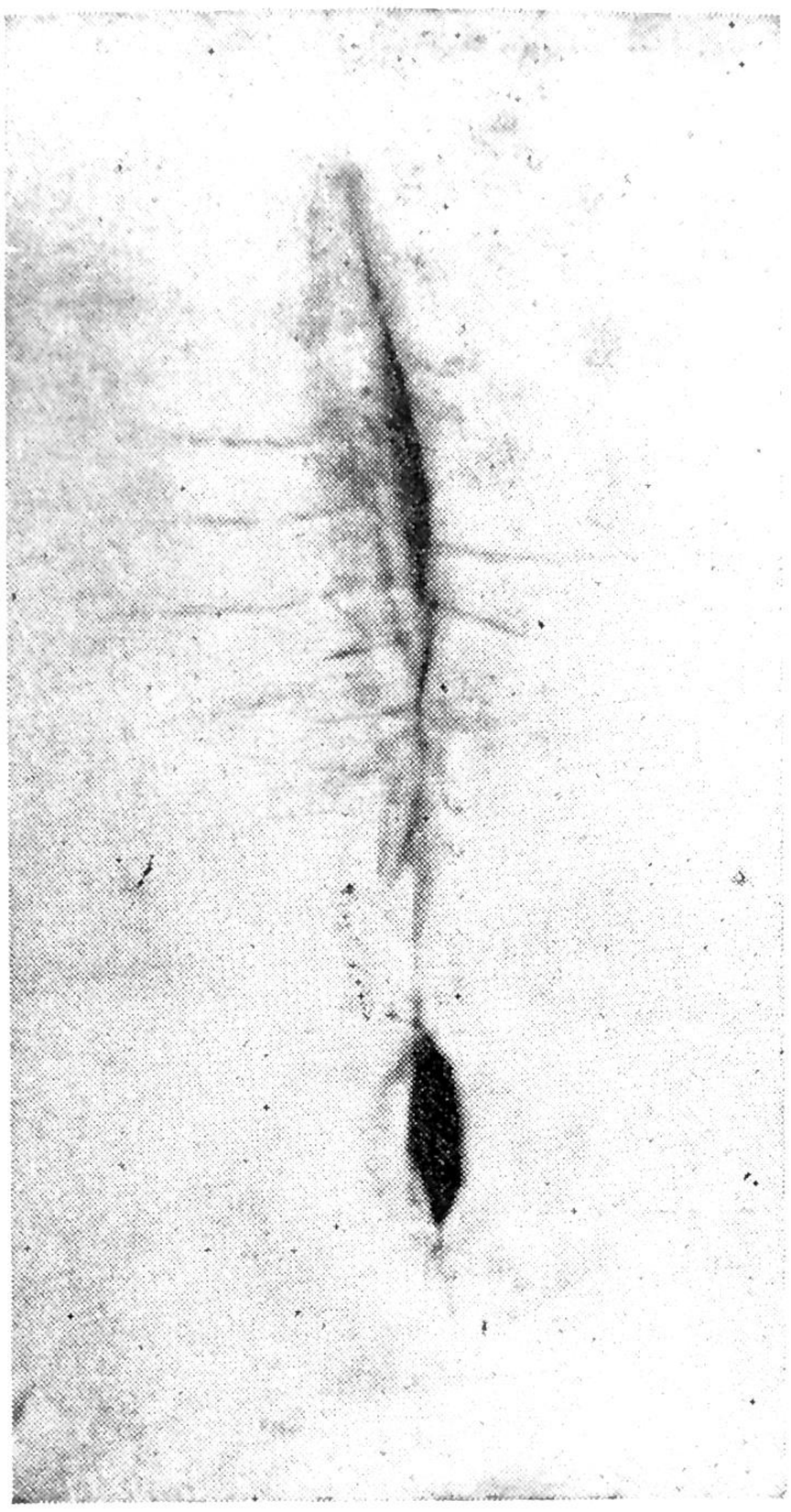


Fig. 3 : Female genital aperture and anus in normal condition.

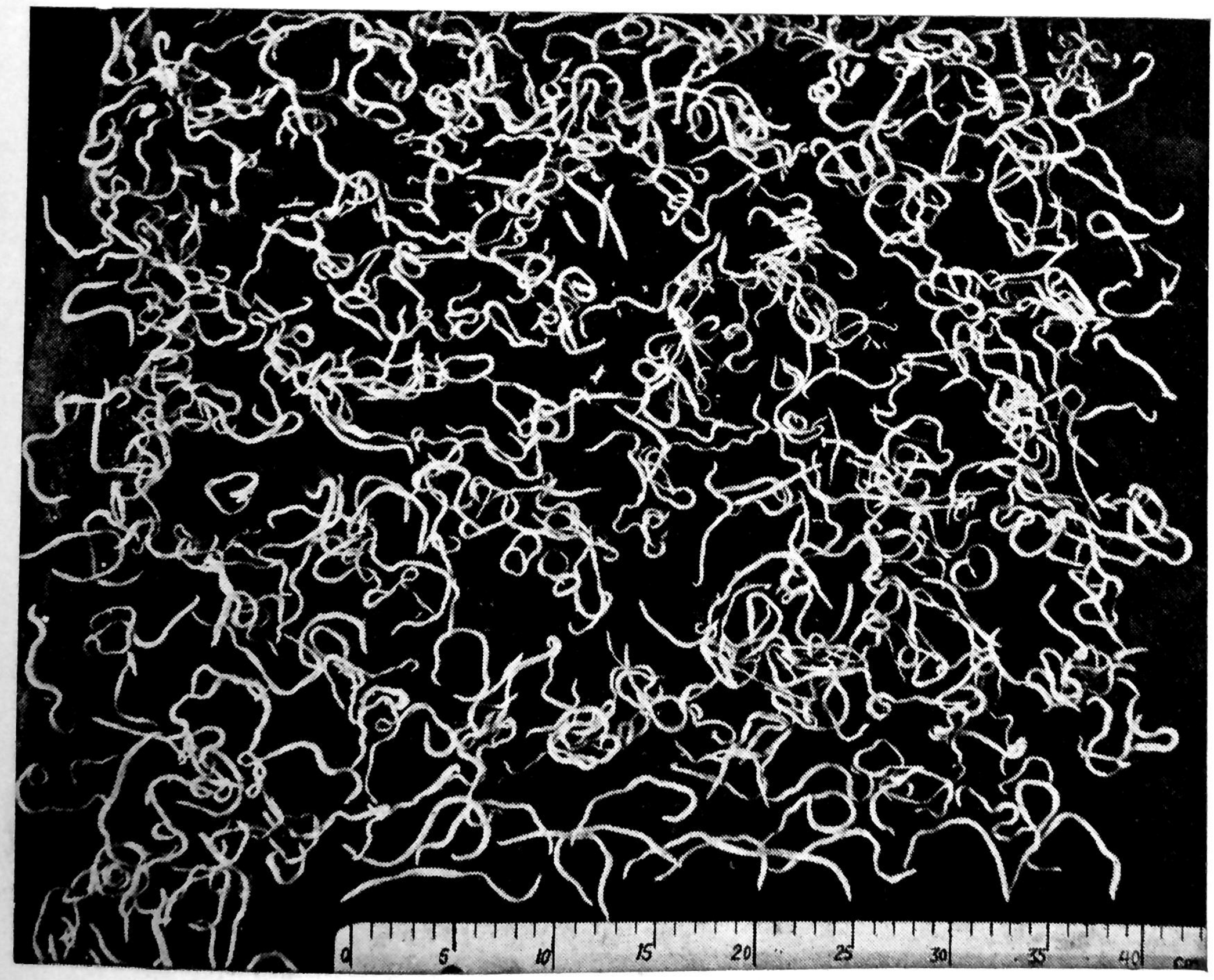


Fig. 4 : 540 worms (*P. halicores*) obtained from stomach shown in Fig. 2 of this plate.

THE STRUCTURE OF THE DUGONG KIDNEY

BY

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Interest in this aquatic mammal arose when some time ago **Prof. H. A. F. Gohar, Director** of the **Oceanographic Institute** at al **Ghardaqa** on the **Red Sea,** kindly presented this department with a young female specimen. This interest was further sustained by a number of other presents made on later occasions, and consisting each of a collection of isolated viscera of the same species, *Dugong dugong*. For all these valuable gifts, as well as for helping with some of the relevant literature, we cannot be too grateful to the donor Dr. **Gohar.**

Among the numerous peculiarities of dugong anatomy the kidney presented a remarkable example, and probably for this reason was made a subject of detailed study by a number of investigators. Nevertheless, perusal of the available literature — Freund (1910), Riha (1911), Pétit (1925) and Osman Hill (1945) — still leaves a great deal to be desired on certain fundamental points, e.g. the behaviour of the ureter within the kidney and its relations to the renal medulla and the renal sinus. The presence of an adequate number of kidneys was deemed therefore a sufficient justification for re-investigating the subject in an attempt at forming an integral view of this unusual type of kidney. In the course of the investigation certain facts, not previously noted, came to light and are here included.

DESCRIPTION

Sections of the kidney will be examined first. The cut surfaces of an organ sectioned in the coronal plane are presented in Pl. I figs. 1 and 2. The cortex is even in thickness but the line of its junction with the medulla appears scalloped. The projections between the scallops give attachment to certain folds, which appear mesentry-like, enclosing each a vascular bundle and projecting into a space of its own. The spaces

are crescentic and the folds appear triangular in cross section. They cut the outer zone of the medullary substance at regular intervals all round the circumference of the organ, the series being interrupted only about the poles. The central cone of the medulla is compact and lighter in colour than the peripheral zone. The medullary substance of the kidney is sharply divided into cranial and caudal halves by a plate of tissue of a very curious structure. The ureter as seen in these figures can be conceived as dividing, rather vaguely in a Y-shaped manner, into two wide but short branches, one cranial and one caudal. The lateral borders of these branches form together a short continuous line, which is curved inwards. The absence of a definite angle on this line leaves an impression that those uretric branches are so confluent with each other that they may be thought to form one common dilation on the ureter, crescentic in shape and receiving the duct at the middle of its convex border. For the present, the main point to be noted is that the ureter here manifests a disposiiton towards symmetry about a transverse plane that passes through the centre of the kidney. Therefore, the segment of ureter — which can be considered either as a short branch or as one half of a small dilatation — will be merely termed a connecting segment, because it actually connects the ureter proper to a further portion of ureteric lumen. The side walls of the connecting segments can be been to spread peripherally in three directions :

(a) **Laterally.** At each end of the short curved lateral border, noted above, the wall can be seen to be smoothly everted and drawn in the lateral direction. The cranial and caudal eversions of the same wall gradually approach each other until they finally meet, blend and ultimately gain attachment to the deep surface of the renal cortex. The blending of those eversions causes an extra-ureteric space to become enclosed between them, and the contents of the space may be mistaken for ureteric wall-tissue. The space is occupied by some small vessels burried in a mass of areolo-fatty tissue easily distinguishable from the compact tissue of the ureteric walls. It is this combination of both ureteric and extra-ureteric tissues that produced the plate which divided the renal medulla in halves. The fact that it was cut across in sectioning the kidney indicates that the plate spreads in a transverse plane across the centre of the organ. In view of its position, because it presents a very distinctive feature of the dugong kidney and because it shall provide a useful landmark, the plate will from now on be called the central transverse plate, c.t.p.. The ureteric lumen can be seen to extend as a narrow chink on either side of the plate, separating it from the base of the corresponding medullary mass.

(b) **Ventridorsally** and (c) **polarward.** The part of each side-wall of a connecting segment, which did not contribute to the formation of the c.t.p. can be seen to be prolonged to some extent toward the corresponding kidney pole, and to possess a lateral and a medial border. The lateral border is continuous with and at a right angle to the c.t.p..

It is free and actually everted under cover of the medullary substance. The medial border of the same wall, on the other hand, had been cut when the kidney was sectioned. The full extent of the ventral and dorsal walls of a connecting segment, is not exposed in the present figures, but it may be mentioned that the ureteric lumen extends also in the polar direction under cover of the medullary core.

The prolongation and eversion of its walls in various directions, in the manner described, indicates that each connecting segment opens up into a dilated space, and is not merely prolonged in any one direction. The dilated space is so encroached upon by medullary substance that its lumen, where it is opened in the sections, appears as chink-like clefts between the medulla and the parieties of the dilatation. There is obviously two such ureteric dilatations, one cranial and one caudal, each occupying one half of the kidney and serving it alone. The two dilatations come in contact with each other outside the ureter, and their contiguous walls become partially blended to form the central transverse plate, whose mode of formation assumes now a very special significance. The morphological value of these dilatations at the beginning of the ureter, will be deferred to the discussion at the end of this account.

The photographic picture presented in Pl. I figure 3 is a close-up of the central region of the ventrimedial segment of a kidney sectioned obliquely in a vertical plane between the coronal and the sagittal; the medullary substance was partially removed. The ureter is not visible here, thus indicating that the section passed lateral to it severing the c.t.p. from end to end. The difference in texture between the structural elements in the substance of the c.t.p. is obvious in this figure, which also reveals some new features not noted previously. There is a well-defined aperture on either side of the c.t.p.. These spertures lead into the ureter and so define the junctions between its connecting and dilated segments; they will be referred to as the connecting orifices. Each orifice opens at a corner of the corresponding dilatation, is obliquely placed and possesses a sharp dorsal lip and two angles, one lateral and centralward, the other medial and polarward. The eversion and extension of the mucous lining of the ureter round each orifice, as well as the manner of formation of the c.t.p. of which a considerable portion has been exposed, all these features are abundantly clear and need no further description. The presence of the orifices combined with the eversions

of the dilatations over the connecting segments both accentuate the difference in dimensions between these portions of the ureter.

The ureteric membrane everted over the dorsal lip and angles of each connecting orifice, takes the form of a three-sided fold, which extends centralward and will of course envelop the corresponding connecting segment. The approximation of the opposite folds to one another results, not only in the production of the c.t.p., but also in hiding the connecting segments and obscuring the outer aspects of the orifices. Two dissections, in which the ureter and its connecting segments are exposed from the outside, are presented in Pl. I figure 4 and Pl. II figure 1, which should be examined together. The specimens confirmed certain previous observations and revealed some fresh ones.

(a) Partial removal of the areolar tissue in the substance of the c.t.p., without anywhere opening into the ureteric lumen, proved again the independence of that tissue from that of the ureteric wall.

(b) The ureter presented a free curved border, short in the cranio-caudal direction and common to both connecting segments. At either end of this border, the walls of the corresponding segment became reflected back on themselves in the form of a three sided fold, which was open towards the hilar cleft on the medial side of the kidney, Pl. I fig. 5.

(c) There is a noticeable discrepancy between the amount of prolongation of the dorsal and that of the ventral walls of the connecting segments. The dorsal wall appears as if it terminated abruptly at the connecting orifice. This appearance should be qualified however. It was found that the muscular layer in this wall indeed terminated abruptly at the orifice, but the mucous layer alone became sharply enverted over the muscular edge. The mucous membrane adhered firmly to the outer surface of the muscular sheet for a little distance in the vicinity of its edge. The condition is one of telescoping the muscular into the mucous layer, and this explains the sharpness of the dorsal lip of a connecting orifice. The ventral wall of the connecting segment, on the other hand, extends beyond the orifice, first laterally to some extent and then turns polarward, reaching as far as the pole. As it proceeds in the polar direction that extension of the ventral wall undergoes a subtle twist so that it gradually comes to be on the medial instead of the ventral side of the corresponding ureteric dilatation. This ventral wall-extension included both the muscular and mucous coats throughout its whole extent. Its fate will be shortly considered but it may be mentioned here that it also suffers a complicated process of eversions along its edges.

The central transverse plate (c.t.p.) has so far been noted only in cross section. It will now be looked at from another point of view,

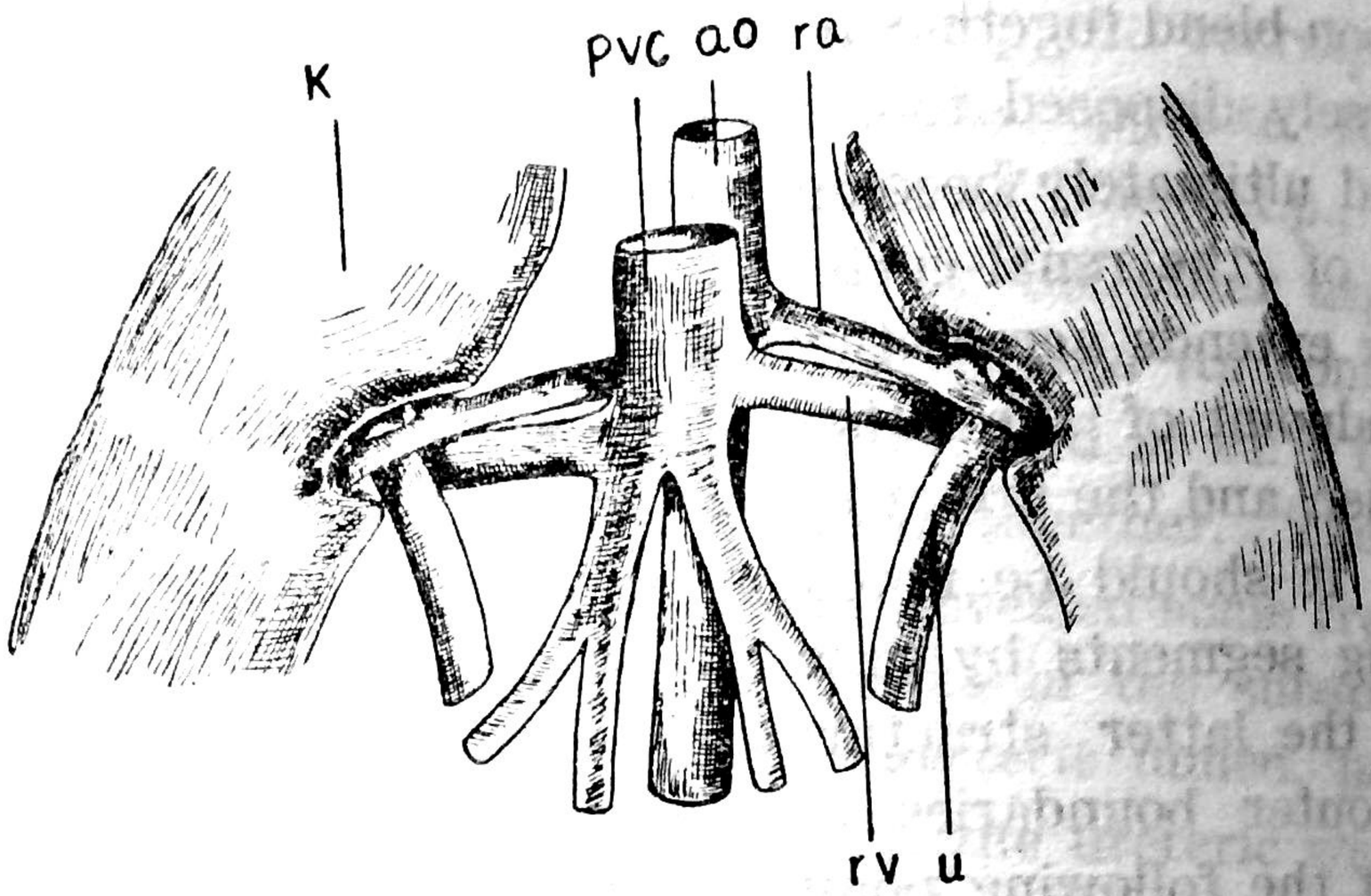
Pl. II figures 2 and 3. As the three-sided folds noted above approach each other near the centre of the kidney, each fold becomes bent on itself on all three sides. The expansion of the mucous membrane, after that bending produces a fan-shaped sheet. The cranial and caudal fan-like sheets soon blend together to form the c.t.p. which will be fan-shaped and transversely disposed too. The plate becomes attenuated near its periphery and ultimately becomes attached by a serrated border to the deep surface of the renal cortex. The line of attachment of the plate to the cortex extends across the kidney from the midpoint of one hilar lip to the midpoint of the other. The plate rides astride the lateral ureteric border, and the ureter appears to serve, as it were, as the handle of the fan. It should be noted again that the everted mucous mem- its connecting segments by vessels and areolo-fatty tissue. The space occupied by the latter structures represents, by definition, the renal sinus. The outer boundaries of the sinus were very adherent to the contents, but the following points about the sinus could be ascertained.

The deeper and central part of the sinus is lined by and enclosed between the two laminae of the c.t.p.. The space is larger on the ventral than on the dorsal aspect of the ureter because the main arteries pass ventral to the connecting segments; but the two portions of the sinus are confluent with each other over the lateral ureteric border.

The ventral and dorsal sides of each three-sided mucous fold (Pl. I fig. 7, smf.) line each half the deep surface of the corresponding hilar lip, and extend to the line of cortico-medullary junction on that surface. The cortex and the fibrous capsule covering it extend only for a short distance on the deep surfaces of the hilar lips, thus lining but a small zone of the central part of the renal sinus. Those sides of the mucous folds ultimately meet and fuse with the fibrous capsule at that line of cortico-medullary junction, where together they become attached to renal substance. The cranial or caudal extent of the renal sinus is determined by the vascular bundles, extending in those directions. The vascular pattern may then be considered here.

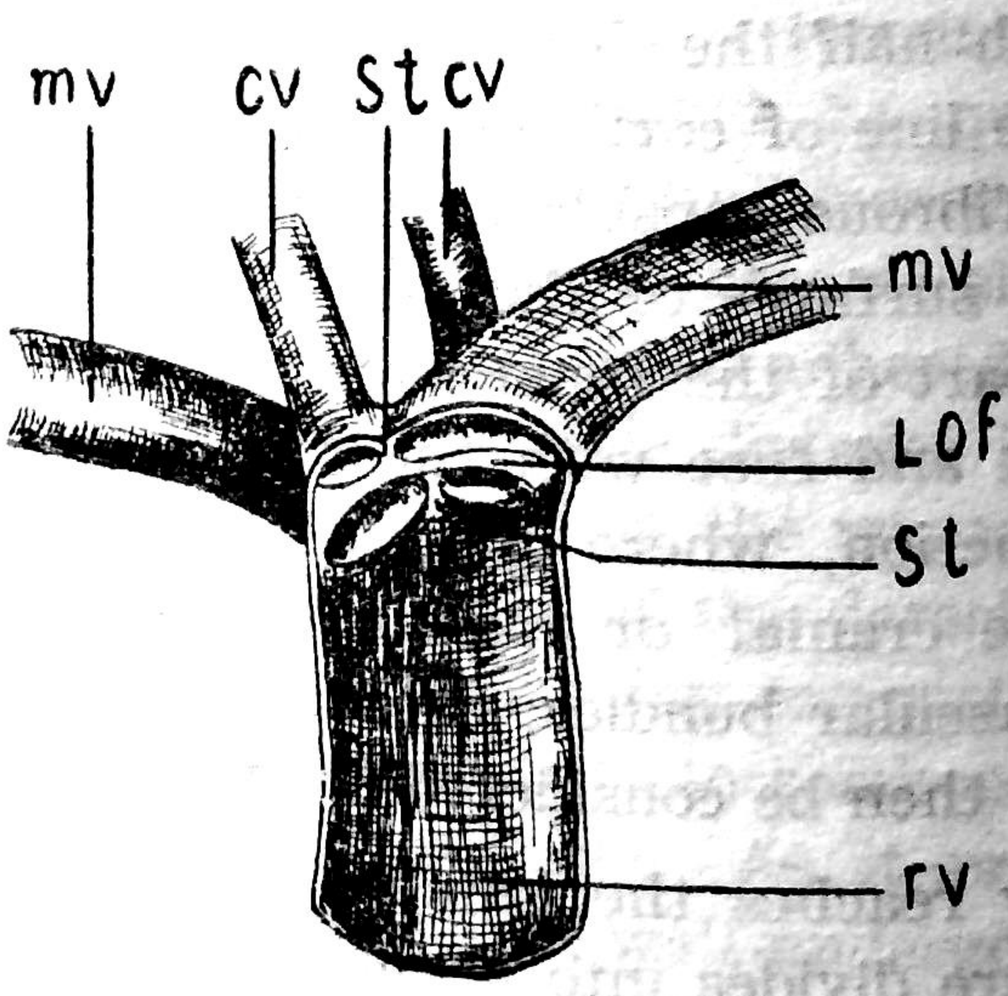
The renal artery reaches the kidney at the anterior (cranial) end of the hilum, and there divides into an interior and a posterior (caudal) branches. The former branch turns cranially and immediately disappears into the kidney, but the latter runs outside the organ for some distance before it also dips into it, Text-fig. 1. The external portion of the posterior artery passes ventral to the ureter, which passes through the posterior end of the hilum. The renal artery is always accompanied by two nerves of considerable size, which break up into a plexus over it. An offshoot of the plexus accompanies each terminal branch of the vessel. The renal

and cranial to the ureter. Its mode of formation could not be ascertained through the hilum, and had therefore to be examined from inside its lumen, when it is seen to be produced by the meeting of two major



Text Fig. 1

and two minor tributaries, (Text-fig. 2). The major vessels extend each towards a kidney pole, the minor ones are directed laterally. The orifices of these tributaries into the main vein were found to be separated by certain folds. A large oblique fold separated two pairs of orifices



Text Fig. 2

one large and one small, in turn separated from one another by a small fold. The folds obviously serve to prevent the clashing of blood currents coming from different directions and to turn them all towards one destination; the oblique fold intervenes especially between the strong and opposite currents carried by the major tributaries.

As they get into the central part of the renal sinus, the vessels get firmly adherent to its outer boundaries, which have been seen to be mainly formed of reflected ureteric mucous membrane. They arrange themselves into two main bundles, one for the anterior and one for the posterior half-kidney. Each bundle includes one terminal branch of the renal artery and one major tributary of the renal vein. The posterior artery gives its first branch at the centre of the kidney; this branch is unpaired and runs laterally for some distance before it divides into two smaller vessels, which bury themselves, together with the two minor venous tributaries, in the areolo-fatty tissue of the c.t.p.. Each main vascular bundle applies itself, while in the central part of the renal sinus, to the ventral aspect of the connecting segment of the ureter. But the ventral wall of the segment has been seen to become prolonged into the parieties of both ureteric dilatations where it undergoes a subtle twist as it extends towards each kidney pole. The vessels become completely enveloped by the dilatation parieties, as these are folded on them in the manner mesenteries envelop the viscera, as seen in a transverse section of the kidney about midway between its centre and pole, (Pl. I fig. 8). The vascular fold is triangular in cross section and attached at one angle to the deep surface of the cortex. It projects into the main cavity of the dialation, which appears U-shaped in the figure. The cavity separates the fold from medullary substance on all sides. It should be noted that the cavity of the ureteric dilatation is entirely on the outer surface of the medullary mass, and that it is about equally bounded by the parietal fold, on the one hand, and by the medulla, on the other. The epithelial lining of the cavity becomes reflected from the surface of one tissue to that of the other at the line of attachment of the mesentery-like fold.

If the space of unusual boundaries described above is accepted as renal sinus because it surrounds the ureter and contains the main vessels, the extensions of that space and of its boundaries over the same vessels, should also be considered as renal sinus; and similarly the same idea should apply to any side extensions of those parieties enveloping the branches of those vessels. In that case the renal sinus of the dugong kidney would have a very extensive and irregular pattern pervading the whole organ.

The parieties of each ureteric dilatation, in as far as they have been examined, consist about equally of medullary substance, on one side, and of prolongations of ureteric wall, on the other. The ureteric prolongations assume an L-shaped form, the short limb being the c.i.p. and the long being the fold enveloping the main vessels going to the same half-kidney. The cavity so bounded has but little depth, but

it presents the main part of the dilatation cavity. It gives out a ventral and a dorsal sets of side-recesses, which extend along the side-extensions of the main longitudinal fold. The cross sections of these side-recesses and extensions have been noted in the coronal sections of the kidney to traverse the outer medullary zone without being completely buried in it, (Pl. I figs. 1 and 2). In order to find further about the dilatation parieties and the cavity outline, two preparations were made, (a) one half-kidney, cut on one side only and from which the medullary substance had been removed, thus exposing the whole system of parietal folds, (Pl. III, fig. 1), and (b) a celluloid cast of the cavity, (Pl. III, figure 2). The following account is based on a consideration of both preparations together.

The connecting orifice opens in a corner at one end of the dilatation. The longitudinal parietal fold, enclosing the main vessels, gives a ventral and a dorsal set each of 5 - 6 side-extensions. The cut points on these extensions, Pl. II, fig. 10), show that each member of the one set joins an opposite — but not necessarily corresponding in number — member of the other set. This union of opposite side-extensions leads to the formation of a series of hoops, disposed transversely along the long axis of the kidney. These hoops are themselves connected to each other by a number of tiers of intertransverse arcades. The c.t.p. is connected on each side to the nearest hoop of the corresponding dilatation by a number of such arcades (Pl. I figure 3). Thef inal result of these connections is that the vessel-carrying folds of each ureteric dilatation form an independent closed network. The hoops and arcades are all like the main longitudinal one, in being wedge-shaped, in carrying vascular bundles and in gaining attachment at the cortex by an attenuated border. The renal sinus can then be said to have also a network pattern, composed of a central space connecting two symmetrical systems of recesses.

Whenever the hoops were cut transversely they appeared as mesentery-like folds of considerable height, projecting each in a narrow space, U-shaped in cross-section. These spaces proved to be side-recesses of the longitudinal portion of the main ureteric dilatation, corresponding to, and spread over the side-extensions of the main parietal fold, each joining the main cavity by a small aperture. Thus, when the parietal side-extensions were found to form continuous hoops, the side recesses were thought to form continuous spaces encircling the compact core of the medulla. But the cast, (Pl. I fig. 9), suggested strongly a discrepancy in behaviour between the vascular side-extensions and the related recess of the main cavity. Each recess extended along the corresponding extension as far as the lateral side of the kidney, but there it

ended blindly. The mutual ventral and dorsal recesses frequently overlapped each other on that side of the kidney. It occurred, in a few instances, that a small connection took place between such a pair of recesses, but there is doubt that this might have been due to over-pressure during the preparation of the cast. In the case of arcades however, each arcade had a small recess in relation to either end; these small recesses never joined each other, and more frequently they remained wide apart leaving the middle portion of the arcade free to get adherent to medullary substance. The discrepancy in behaviour between recesses and parieties thus raises a real problem, because while the muscle-fibrous elements of the ureteric wall — as judged by their obvious continuity — have been seen to pervade the kidny in the form of a network, the ureteric lumen and its epithelial lining extend in the form of a labyrinth, which consists of a main central part giving on either side a set of blind recesses. The problem will be further discussed later in this account. A more detailed description of the cast will be mere repitition and serve no useful purpose. The cast of the dugong kidney provides, however, solid evidence of certain basic facts noted above.

1. The cranial and caudal dilatations of the ureter are entirely independent of each other, connected only indirectly by joining the same duct.

2. The chink-like space between the c.t.p. and the medullary mass on either side crosses the kidney from side to side without interruption, showing that it is an actual part of the main L-shaped cavity of the ureteric dilatation.

3. The long limb of the L is obviously infolded by the main vascular bundle; and similarly each side-recess is infolded by its own vascular bundle.

The medullary substance of the dugong kidney as a whole may now be considered. It is completely divided into two halves — a cranial and a caudal — each related to one ureteric dilatation, and the epithelial lining of the latter becomes continued over any exposed surfaces of the former. The transition from parietal to medullary epithelium occurs at the lines of junction of the parietal folds to the deep surface of the cortex, where the medulla is also attached. The folds and medullary substance are, however, separated from each other by the chink-like recesses. The medullary mass in each half-kidney is conical in shape, with the base resting against the central transverse plate. The outer surface of the cone is marked by a system of grooves corresponding to the labyrinth system of the main ureteric dilatation and its recesses. The parietal side-folds and the recesses related to them cut deeply in the outer zone of the medullary cone and encircle its central part, (Pl.I fig. 8).

The central core of the medullary cone is compact, cylindrical and threads through the series of transverse parietal hoops. This appearance of threading appears as if it seem to take place inside the dilatation cavity, but, in fact, it does not. The manner of reflection of the epithelial lining of the ureteric dilatation, (Pl. I figs. 1 and 2 and Pl. I fig. 8), from parietal folds to medulla shows that the latter remains outside the cavity, merely invaginating its epithelial lining in a complicated manner. The medullary substance may be conceived as arising from the cortex in separate pyramidal portions. Each pyramid would be projecting into the ureteric dilatation, and had it remained isolated of all other pyramids it would have been covered with ureteric epithelium on all sides. But these medullary pyramids do not remain independent of each other; the apical portions of those pyramids enclosed between every successive pair of transverse hoops become fused together, with the result that a discord segment is formed between such a pair of hoops. These discoid segments themselves fuse with other, but only through the intervening hoops. In this way, it seems, was produced the compact medullary core, and came the recesses to be so much cut off the main cavity, communicating with it through small apertures only. The forms of the bases of the medullary pyramids are clearly shown in the cast, Pl. III fig. 2. The medullary cone within each half-kidney presents towards the corresponding cavity a concave surface, i.e., no projecting common papilla is present in the dugong kidney. In the present material, previously fixed in formalin, the medula exhibits the already noted feature, viz., the differentiation into an outer dark-grey and an inner light-brown zones. The outer zone is interrupted by the vascular folds and related recesses, but the inner zone is compact.

The arrangement of vessels in the dugong kidney appears to follow the usual mammalian pattern. The renal artery divides into a cranial and a caudal branch, each supplying the corresponding half of the organ. The main artery for a half-kidney is enclosed in the main longitudinal fold of the corresponding ureteric dilatation, and gives a ventral and dorsal set of transverse vessels, which run through the side-extensions of that main fold. Since the side-folds run between the bases of the medullary pyramids, the vessels, enclosed in them, naturally correspond to the interlobar arteries of the usual pattern. As a matter of fact those parietal folds, with their enclosed vessels and attachment to cortex really correspond to renal columns in a kidney such as the human. Each interlobar artery supplies a medullary pyramid on either side and its branches usually run through the intertransverse arcades representing the arciform arteries of the usual pattern. Sometimes the interlobar arteries give branches that pass directly to the cortex without traversing

parietal arcades. This set of arciform vessels will give the interlobular arteries that leave the parietal folds at their serrated borders attached to the cortex. The first branch, given by the main caudal artery, is unpaired and takes origin opposite the centre of the kidney; it runs between the two laminae of the central transverse plate thus behaving like an interlobular artery, differing however in supplying a pyramid from each half-kidney. It was frequently noticed that a parietal fold presented in cross section more than one artery and one vein; this was probably due to the fact that the branches of the main vessels in that fold ran beside it for some distance before they turned into their own folds.

Because of the size of the organ, only a limited histological examination was attempted; and because of the state of preservation of the material examined the results were rather meagre. It was possible nevertheless to verify the presence of all the structural elements of the ureter in the parietal folds of its dilatations. The straight tubules run generally in a radial fashion from the cortex to the central medullary core, (Pl. II fig. 12). The collecting tubules seem here to bend towards the ventral and dorsal sides of the medullary core, where they open opposite the orifices of the side-recesses of the ureteric dilatation. The transitional epithelium lining the dilatation extends for a little distance into the collecting tubules, (Pl. II fig. 13).

DISCUSSION

It was mentioned that the dugong kidney had been studied, in greater or lesser detail, by a good number of investigators. In a review of earlier literature Freund (1910) found that information about the subject was both « scanty and inconsistent ». According to the same review however the dugong kidney was supposed — up to that date — to possess a single common papilla received in a single elongated renal pelvis. In the course of his own investigation, Freund discovered for the first time the presence of a connective tissue plate (which he called a septum) at the middle of the kidney, that caused it to be « divided into oral and caudal halves, only connected together by the cortical mantle and connective tissue ». This was a most significant discovery; it disposed of half of the older view on the subject, because it showed that the dugong kidney possessed two « papillae » and not one. But the same discovery raised two new problems that needed explanation : (a) How would the ureter cope with those two « papillae »? and (b) What was the nature of that plate, which produced such an influence on the structure of the dugong kidney ? Freund answered the first question as follows :

« A true pelvis is not formed, rather the ureter divides after its entrance into two elongated channels... ». But he was so uncertain of the nature of those channels that he had to coin for them the unusual term «Nierengänge » or kidney caudals. Moreover in his attempt to answer the second question Freund contradicted his own answer to the first; he described the plate, as well as a whole series of structurally similar «septa» separating the medullary pyramids from one another, as being «attached at right angles to a longitudinal band, which extends from the pelvis and reaches through the kidney on the medial side of the canals.» The contradiction between the two answers leaves the first question almost unanswered; and the description in the second answer implies that the band and plate together have an independent origin in the kidney which would be a curious condition, itself demanding explanation. Freund's conception of the kidney canals merely as elongated channels marred his otherwise clear and correct description of the renal medulla because of the intimate relationship between the two. This rather lengthy discussion of Freund's work has been undertaken because the points treated above are considered so fundamental that a proper realization of them is essential for formulating an integral view of the structure of the dugong kidney.

Another study of the same subject was carried out by Riha (1911), who also considered that « The ureter divides into two branches, which will form the kidney canals. The two canals provide the reservoir in which the urine is collected without the formation of a renal pelvis.» Like Freund however Riha soon contradicted his own statement about the renal pelvis; in describing the various septa in the kidney; he explicitly derived them from the tissue of the «pelvis walls.» It indeed seems that both Freund and Riha did not find the two kidney canals by any means equal to replace a renal pelvis.

In the course of an extensive study of the dugong kidney, and besides recording his own observations, Pétit (1925) discussed Freund's and Riha's works and included a vast amount of comparative information. Only a few points of special value out of Pétit's long account will however be discussed here. A considerable portion of this account treated with the connective tissue framework of the kidney, the same as the various septa of Freund and Riha, and with its influence on the general architectural plan of the organ. In this respect Pétit claimed that he was able tó distinguish between three systems of « vascular partitions », oral, middle and aboral; and he accused Riha of missing this point of differentiation altogether. But with regard to Freund, Pétit claimed that while the other's schematic reconstruction supported his own view, the « text leads to confusion and explains the figure badly.»

In the light of the present investigation (Pl. II fig. 10), it is possible to state that Riha's preparations were certainly more suitable for deciding the point at issue than Pétit's material, and that Riha could not have missed something that was not there. It was also impossible for us to detect in Freund's schema any support to Pétit's claim, and so we cannot agree to Pétit's views on the medulla, based on those unverified observations. Freund's conception of the renal medulla, with the exception of its relations to the so called kidney canals, still holds good and is comparable to our findings. In connection with the same fibrous framework Pétit recognized — after Freund — the presence of the «middle transverse septum », and he offered an explanation for its distinction from all other partitions in the following way : «It is easy to suppose that it is the result of joining of two partitions at first distinct, come into contact.» The origin and mode of formation of that « septum » (the same as our c.t.p.) as demonstrated in the present investigation, leave now no room for Pétit's suppositions.

On the subject of the renal pelvis, Pétit concluded as follows «the ureter, on entering the kidney, dilates into an infundibulum, which soon becomes constricted and elongated laterally extending more or less towards the poles of the organ », and he then considered « the infundibulum proper with its restricted limits as a real pelvis », and « the arms that prolong it as a stretching of the pelvis itself, determined by the elongation of the kidney ». It is clear then that Pétit has reverted to the original view of a single elongated pelvis, which was held before Freund discovered the division of medulla into halves. He simply elaborated it to such an extent as to make the dugong kidney, in this matter of renal pelvis, similar to that of the horse. Freund connectly felt the need to harmonize between medulla and ureter; but Pétit ignored the pecullar condition of the former in favour of harmonising the latter with the condition in some other species. The present investigation may lend some justification for Pétit's claim of the presence of a slight dilatation at the proximal end of the ureter proper, but this dilatation is in fact accidental, because it merely represents a segment of the ureter connecting between two curious but real dilatations of considerable dimensions.

In a «superficial investigation» of the dugong anatomy Osman Hill (1945) wrote in respect of the ureter as follows : « Traced into the renal sinus, the ureter undergoes a bifurcation into two major calyces,... of equal dimensions.» Here was the first mention of a renal sinus and calyces in the dugong kidney. But again Osman Hill fell into the same contradiction as Freund and Riha; in a diagram included in the account, no bifurcation of the ureter into calyces was shown, but instead

there was an arrow, which «indicates direction of ureteric outflow from pelvis of ureter.» So again the bifurcation of the ureter into mere branches under whatever name they may be designated could not alone satisfy the need for a ureteric dilatation to receive the renal medulla.

It should have now become clear from the above review of literature that the most mooted point in the structure of the dugong kidney was the behaviour of the intrarenal ureter. There has always been felt the need for some dilatation on this part of ureter to receive a corresponding renal papilla. Because of the complicated manner of its expansion within the kidney however the lumen of the ureter is very difficult to expose in sufficient amounts in the usual sections ordinarily used in examining unilobar kidneys. Thus as long as the dugong kidney was supposed to possess a single renal papilla the ureter was accordingly supposed to dilate into an elongated pelvis. But the medulla in this kidney has been shown, beyond doubt, to be divided into completely separate halves, one cranial and one caudal. The ureter has obviously then to conform to the condition of the medulla, and in the sections of the kidney it appeared with sufficient justification to undergo a bifurcation apparently into two elongated branches. The obvious elongation of the ureteric branches and their complicated relations to the medulla obscured their real nature, and they became variously designated, kidney canals, recessus terminalis, arms or prolongations and calyces majores. The dilatation of the ureteric branches, i.e., the expansion of each in more than the longitudinal direction has become in the present investigation definitely established, and their proper significance should now be recognised. Each dilatation lies at the beginning of the ureter and its epithelial lining is continued over the medulla, even into the collecting tubules; by definition such a dilatation should be considered with full justification as a ureteric pelvis. **The dugong ureter therefore is normally dipelvic.** The condition does occasionally occur as a congenital abnormality in the human kidney, Boulgakow and Fahmy (1926). The expansion of the dilatations beyond the ureter in a lateral direction is of particular significance in this respect.

The eversion of the mucous membrane of each ureteric branch is difficult even to suspect after the ureter has been opened, but once it is detected the ureter can be said to burst into a cranial and a caudal pelvis. The part of ureter between the two pelves, the connecting segment, is so flattened and so outlined that it suggests both a bifurcation and a dilatation, but the dilatation, if it exists, is only accidental. The expansion of the two ureteric pelves towards the centre of the kidney leads to their approximation to one another and to their overshadowing the ureter itself. The two pelves can then be said to sit back to back on top of the ureter. Their contiguous

parieties blend partially and produce the central transverse plate, which presents an obvious distinctive feature of the dugong kidney.

The formation of two ureteric pelves is correlated to so many other dual features that the dugong kidney exhibits a cranio-caudal symmetry, about a transverse plane passing through its centre. Such features are : the ureteric pelvis, the medullary moieties, the bifurcation of the renal artery and the two major tributaries of the renal vein. Moreover it is by no means far fetched to assume that, because of its structure, even the renal cortex is divisible into two halves at that central transverse plane. The dugong kidney can indeed be said to be formed of two kidneys almost independent of each other, which have secondarily united producing one strikingly elongated organ.

The ureteric pelvis in the dugong kidney has some peculiarities of its own :

1. The connecting segment of the ureter opens into each pelvis at a corner and not at the centre. This is due of course to the fact that the same ureter serves two separate pelves, which burst out of it directly without any preliminary branching.

2. The main cavity of each pelvis is L-shaped and not exactly basin-like. This is obviously due to the duplication of the pelvis in the same organ and the back to back relationship of the two pelves.

Apart from these peculiarities the ureteric pelvis in the dugung has been found after some brief investigation, to bear resemblances to those of both the camel and the horse. In a general way, it belongs as in the camel to the type commonly known as the buttress pelvis. The network of parietal folds described above corresponds to the system of loculi described for the camel by Tayeb (1948) ; and the casts of the two pelves viz., that of the dugong and that of the camel (plate II fig. 14) are alike in many features. A cast of the camel's ureteric pelvis was described by Grahame (1944), and the description applies in most respects to the cast of ureteric pelvis in the dugong. The similarity between ureteric pelves of the dugong and horse is mainly at the region of the uretero-pelvic orifice. The abrupt termination of the muscular layer on the dorsal aspect, and its prolongation and extension on the ventral aspect are common to both types; that is why both pelves exhibit no symmetry about any longitudinal plane. Moreover the absence of a projecting papilla in the case of the dugong kidney gave reason to many an investigator to find similarlity between it and the recessus terminalis of the horse kidney.

In view of the obvious continuity of the pelvic parieties with those of the ureter no question should arise about the origin of the tissue elements forming the characteristic network of vessel-carrying bands in all those kidney types. The discrepancy between the amount of extension

Plate II

Fig. 10 : One half-kidney, cut on the lateral side, and medulla greatly removed. Co = connecting orifice ; sf = side-folds that form transverse hoops, note the cut points ; u = ureter.

Fig. 11 : Cast of the pelvis of a camel kidney.

Fig. 12 : Showing the radial arrangement of straight tubules. cmj = cortico-medullary junction ; mc = medullary core ; m v = main artery and vein ; St = strainght tubules ; sv = side vessels ; ud = cavity of ureteric dilatation.

Fig. 13 : ct = collecting tubules ; mc = medullary core ; te = transitional epithelium ; ud = ureteric dilatation.

Fig. 14 : Cast of the pelvis of a horse kidney. ct = collecting tubules that open in recessus terminales. rm = recessus medius ; rt = recessus terminalis ; sp = side pouch u = ureter.

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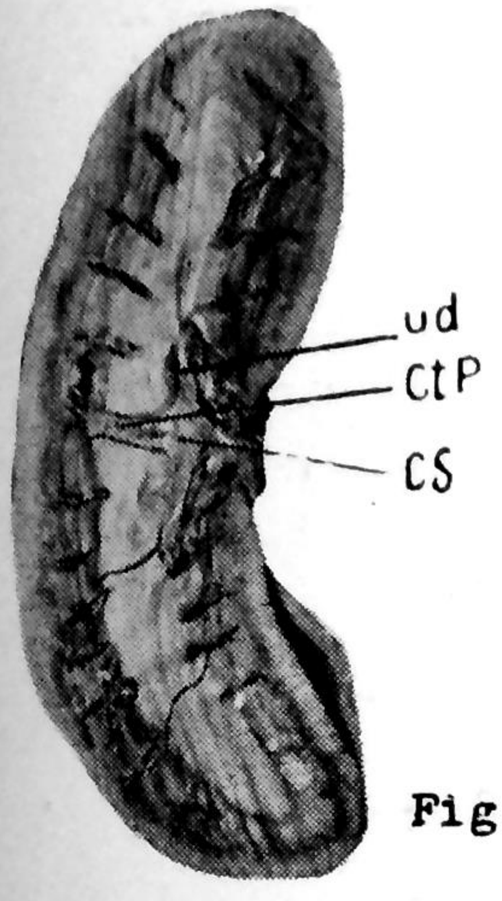


Fig.1

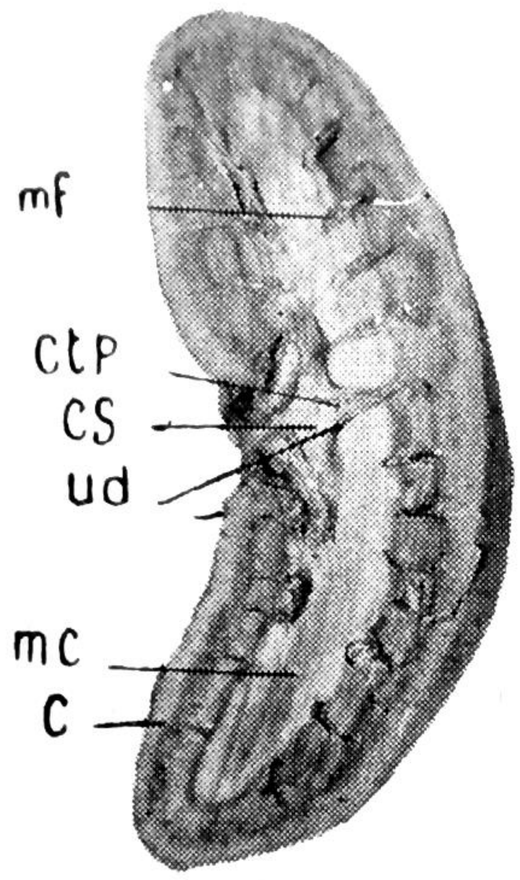


Fig.2

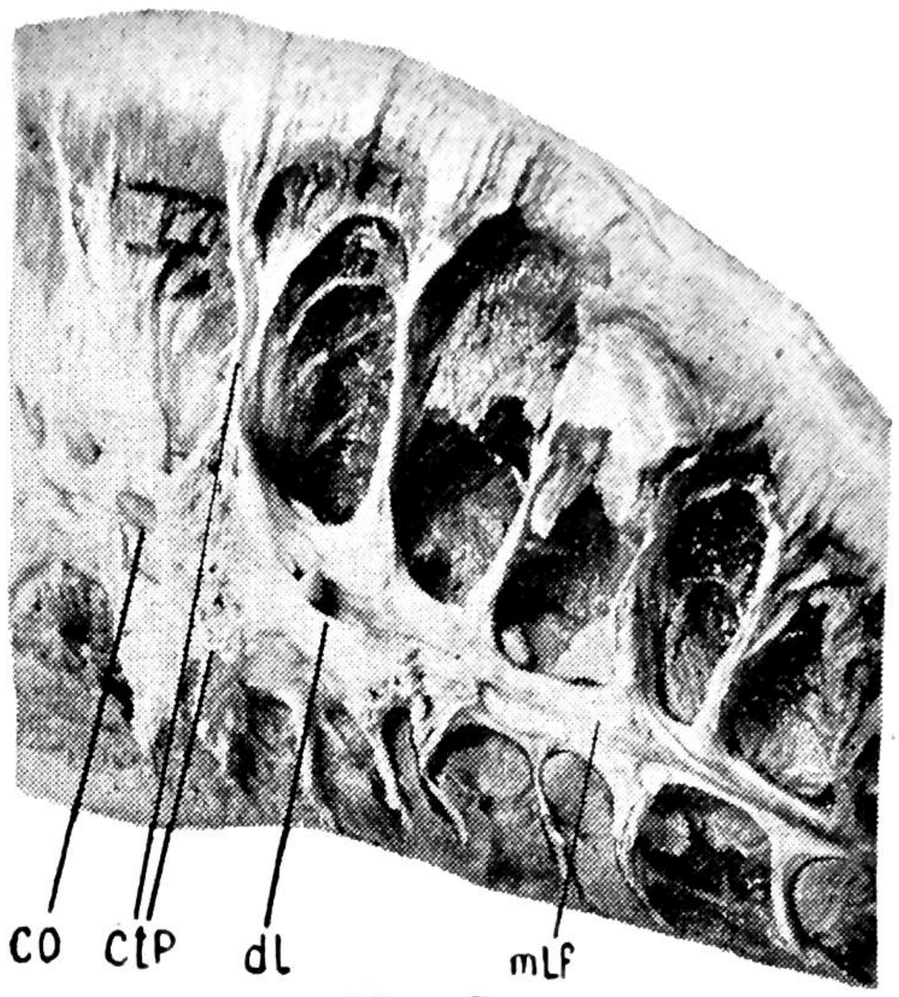


Fig.3

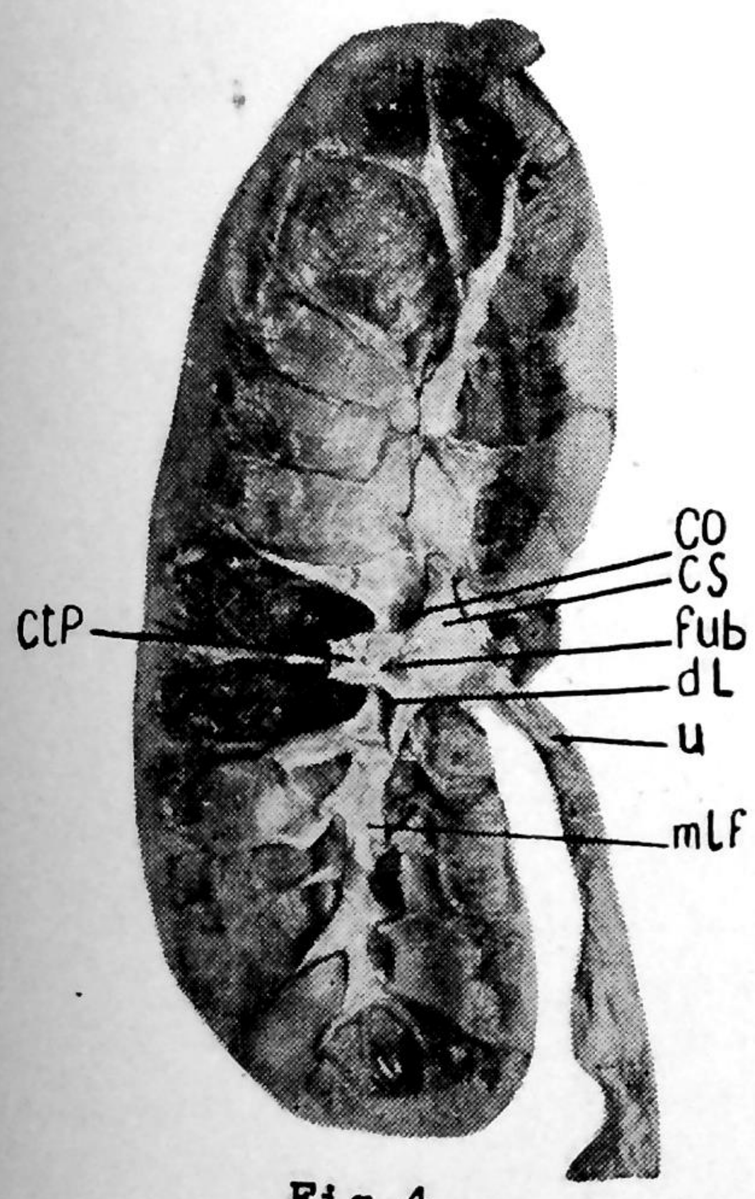


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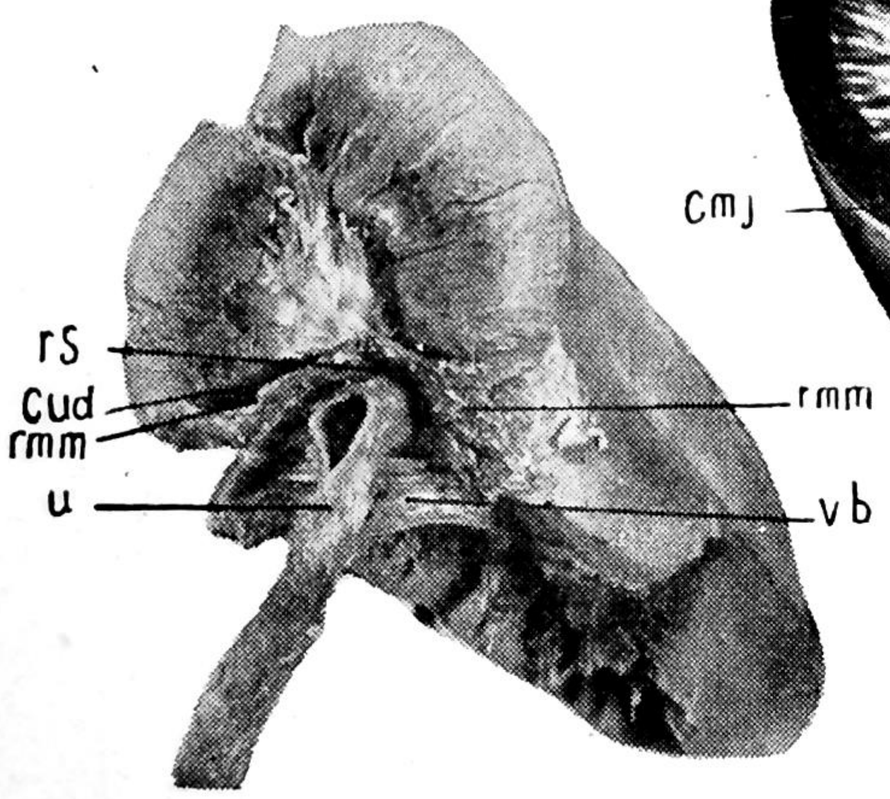


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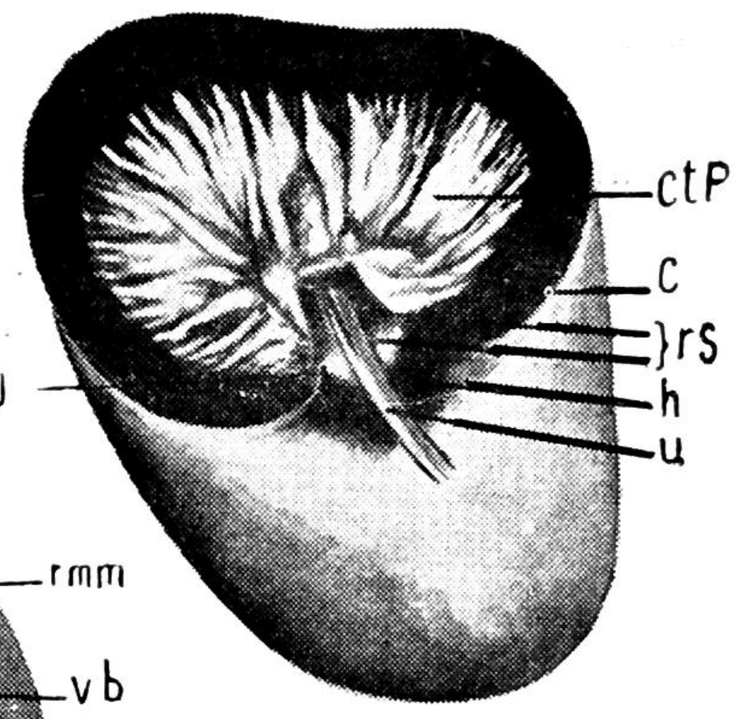


Fig.7



Fig.9

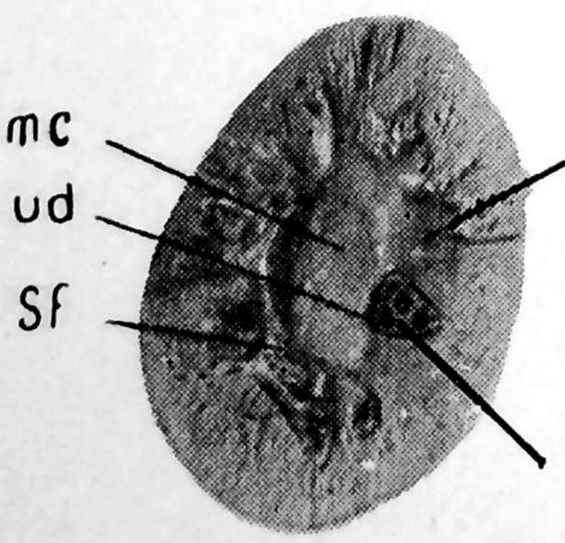


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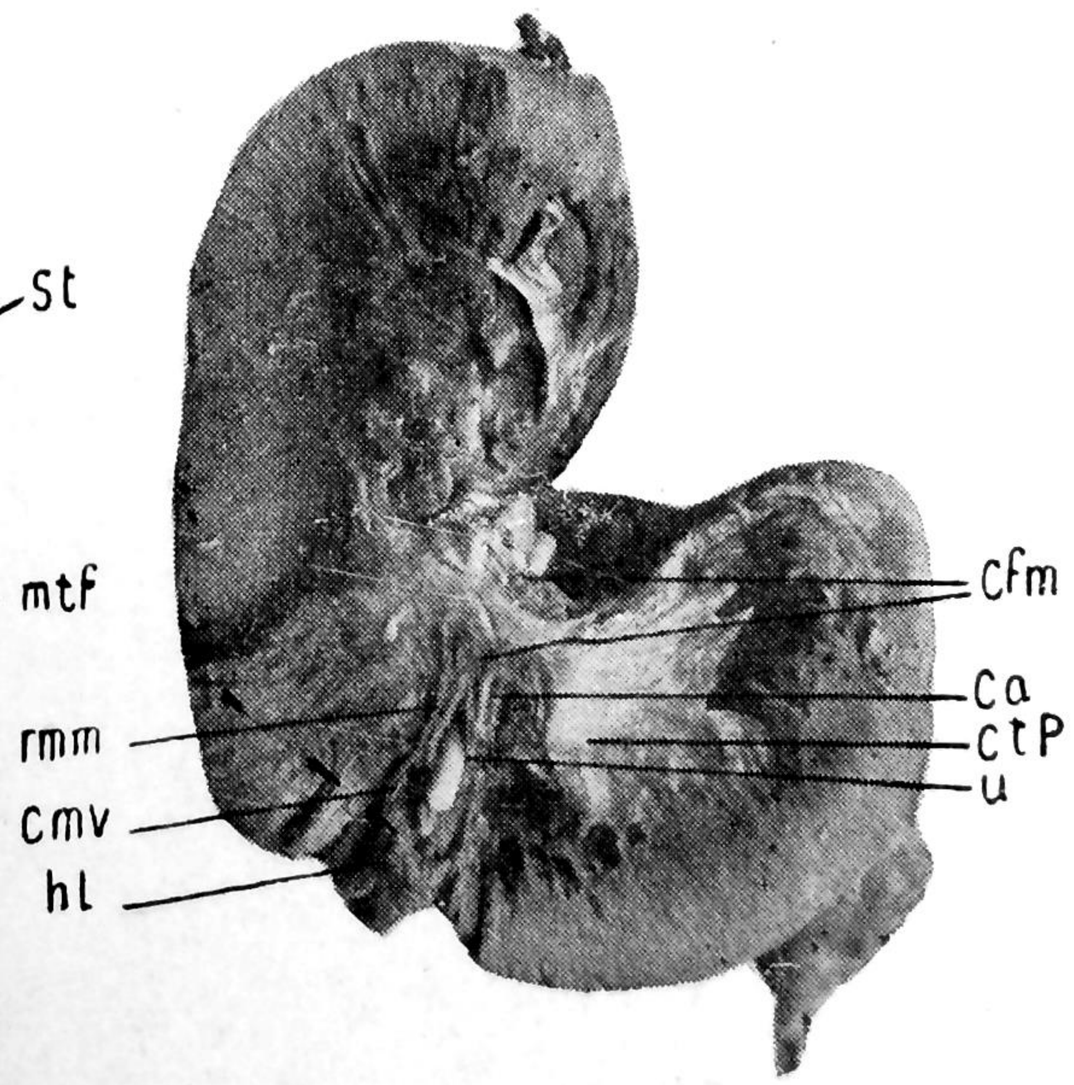


Fig.6

Plate II

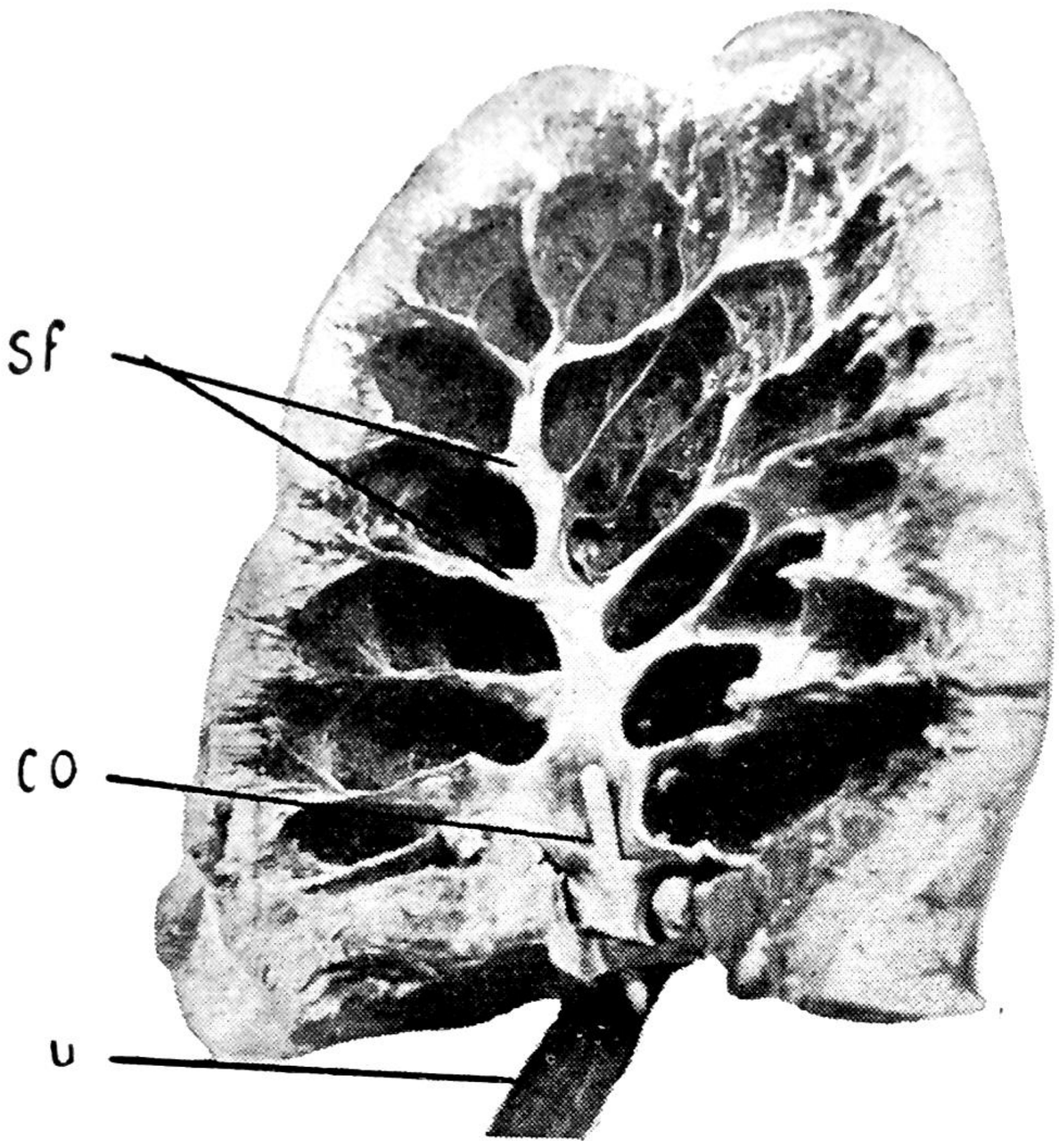
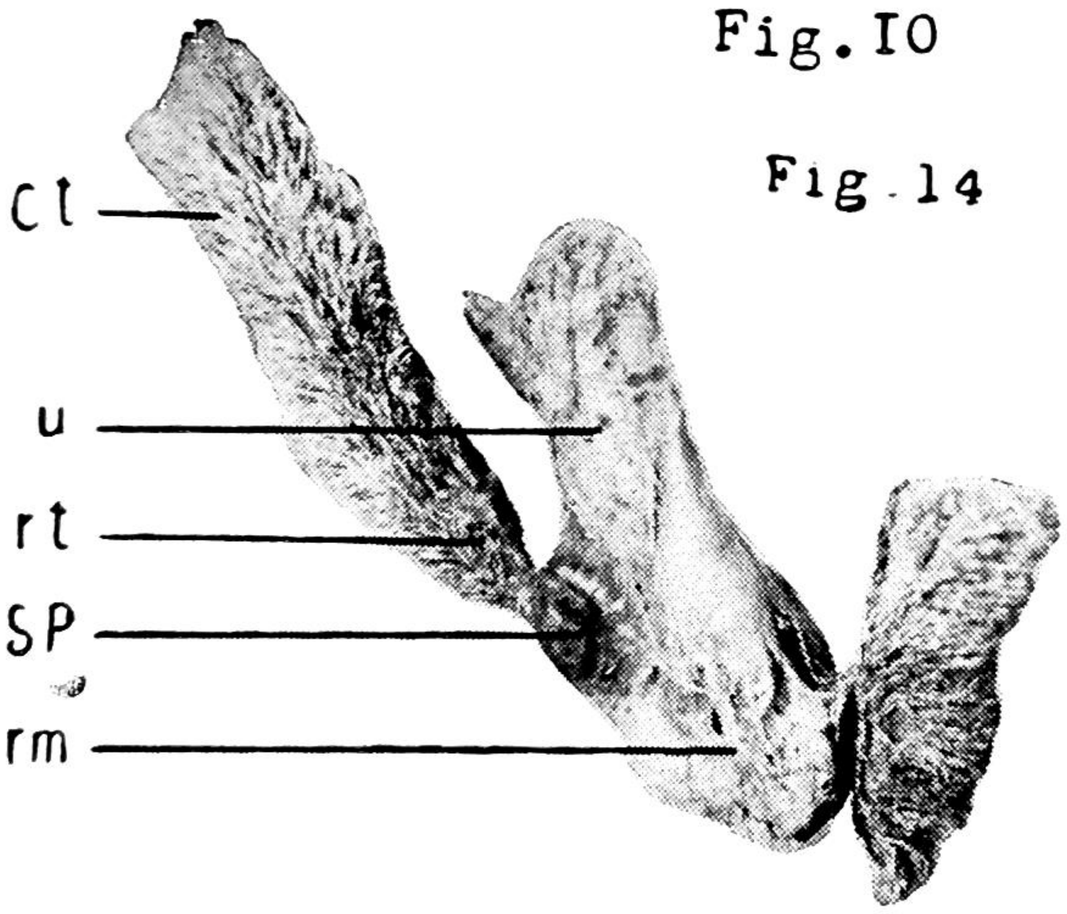


Fig. IO



Fig. 14

Fig. II



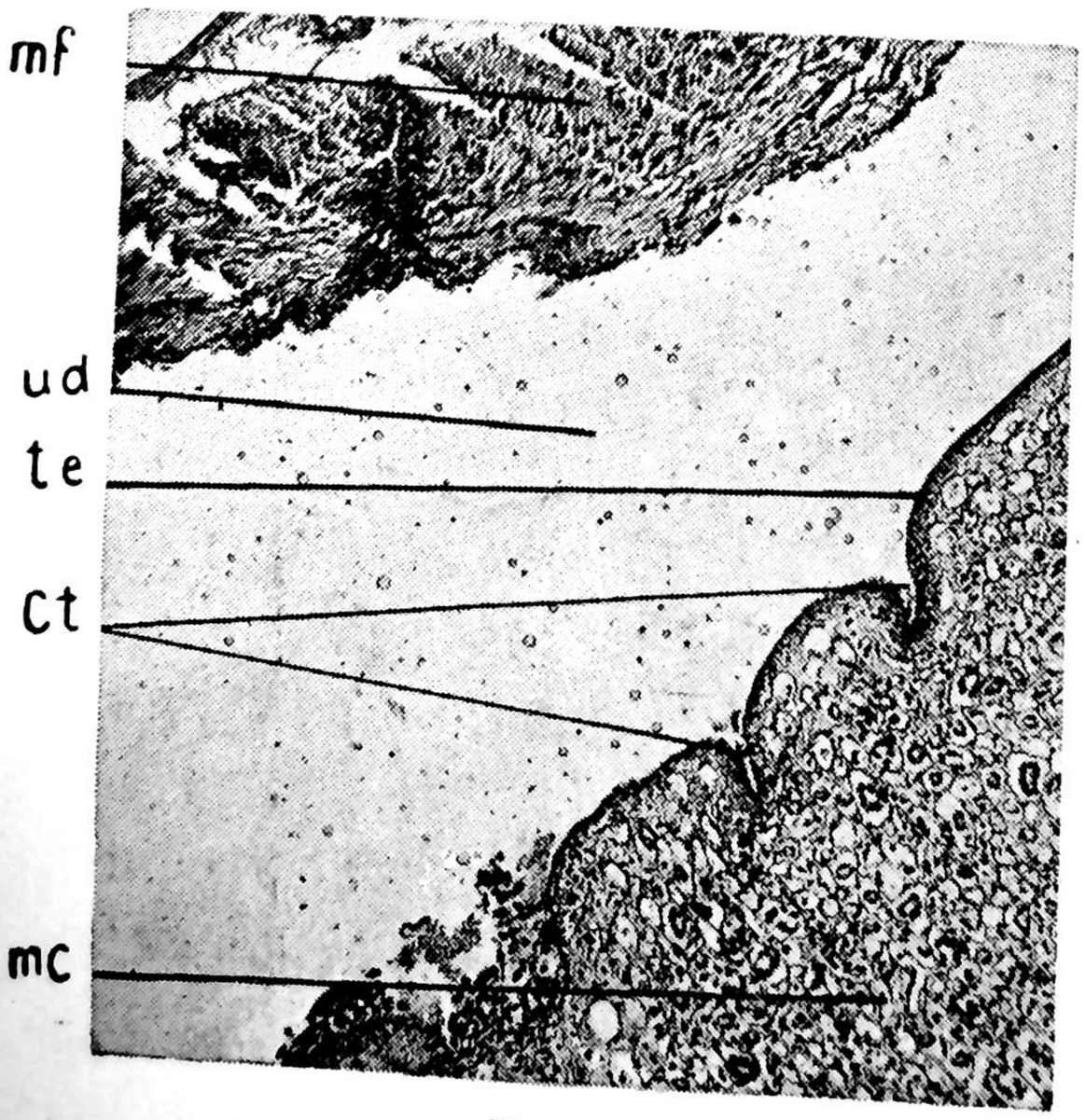


Fig. I3

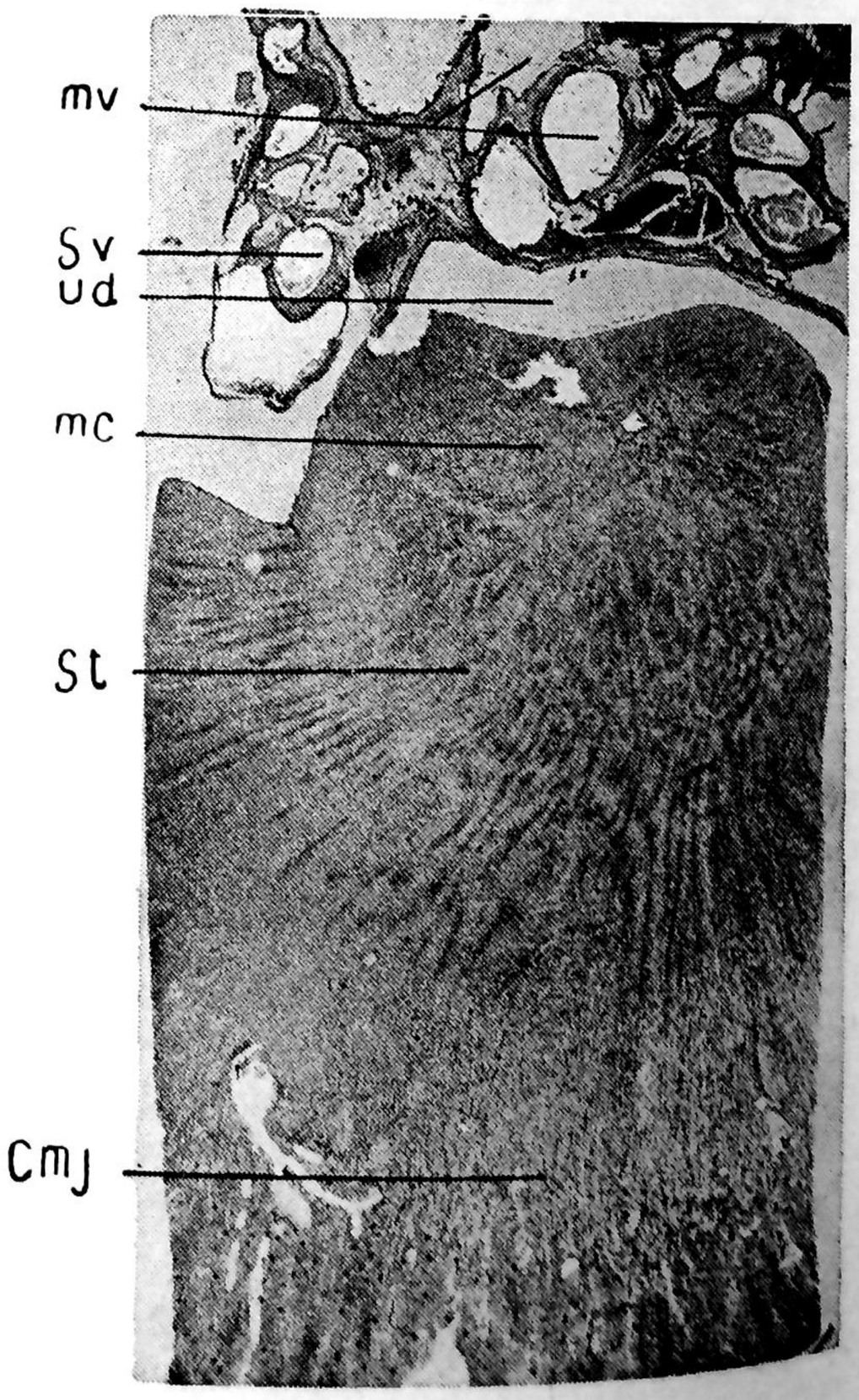


Fig. I2