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SOME ASPECTS OF THE ANATOMY OF THE ROSS SEAL, *Ommatophoca rossi* (PINNIPEDIA : PHOCIDAE)

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ABSTRACT

THE collection, by the British Antarctic Survey, of two complete frozen Ross seals from north-east of the Weddell Sea made possible an investigation of their anatomy. A summary is given of the previous collections of material of this seal, and of the earlier work done.

A description is given of the external features of the two complete seals, stressing those facts that are new or that have been incompletely recorded. Food remains in the stomachs indicate the presence of cephalopods, possibly of large size, and the parasitic roundworms and tapeworms are identified.

The head has been dissected as far as the damage in this area would allow, and particular attention has been paid to the myology. The large size of the eyeball is noted, and the external morphology of the eye given. The nasal cartilages are seen to be modified from the condition found in *Phoca* to provide more efficient closure. The ear has a specialized external auditory meatus, a well vascularized lining to the middle ear cavity and a very thick, bony, tympanic bulla. The ear ossicles are described and compared with those of other Antarctic seals.

The great length and muscularity of the soft palate, the tongue muscles, and the oddly shaped epiglottis are noted. The structure, attachment to the skull, and muscles of the hyoidean apparatus are described, and many of the muscles of the tongue, jaw and pharynx are correlated with the ability to grasp and swallow bulky objects. The trachea and larynx are described, but no evidence is found for the statement in many earlier works that the larynx is distended for sound production.

Thirty-four skulls of the Ross seal have been measured and examined, and the characteristic features noted. The numbers and variation of the teeth are tabulated. The skeleton is described, and particular mention is made of some of the flipper characters, such as the elongated epiphyses and cartilaginous extensions to the digits.

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CONTENTS

I. INTRODUCTION

THE Ross seal, *Ommatophoca rossi* Gray 1844, was first named and described from specimens brought back from the voyage of H.M.S. *Erebus* and H.M.S. *Terror* (Gray, 1844–75). These vessels, under the command of Sir James Clark Ross, made an expedition to the Antarctic during the years 1839–43 "for the purpose of investigating the phaenomena of Terrestrial Magnetism in various remote countries", and the officers were instructed "that they should use every exertion to collect the various objects of Natural History which the many heretofore unexplored countries about to be visited would afford". As a result of this injunction twenty-three pinniped specimens were collected, although very little mention of them is made in the narrative of the voyage. Of the Ross seal, a skull and a skull with an incomplete skeleton were brought home from the Ross Sea (lat. 68°S., long. 176°E.) and these were named, figured and described in J. E. Gray's account of the zoology of the voyage. It is a curious fact that although Gray was obviously aware that this animal had not previously been described he makes no mention of this nor is it obvious from his rather brief account, which deals mainly with the teeth, that it was a new animal. The type specimens are in the collections of the British Museum (Natural History). They are skull 1843·11·16·7, 324 b, and skull and skeleton 1843·11·25·4, 324 a.

No more material of this seal was collected until 1898 (57 years later) when the skulls and skeletons of an adult male and female were brought back by S.Y. *Belgica* of the Belgian Antarctic Expedition, 1897–99. These specimens from the pack ice east of the Palmer Archipelago were described by Barrett-Hamilton (1901) who, of necessity, confined his description almost entirely to the skull and dentition. Racovitza (1900), who was with the expedition, has given an account of the external appearance and some of the peculiar habits of this seal.

The British Antarctic Expedition, 1898–1900, in the *Southern Cross*, brought back four skins and skulls from animals found on the pack ice near Victoria Land. The diary of Nicolai Hanson (1902), the zoologist on this trip who unfortunately died during the expedition, gives some account of the external features of the Ross seal. Barrett-Hamilton (1902) goes into considerable detail on variations in dentition and Wilson (1902) mentions the colour. The skins and three of the skulls are in the collections of the British Museum (N.H.).

The German South Polar Expedition, 1901–03, collected a skin, skull and skeleton from an animal at Kaiser Wilhelm II Land and four skulls from the Weddell Sea. These are now in Berlin and were reported on by Pohle (1927).*

Six skulls and skins were collected by the British National Antarctic Expedition of 1901–04, in the ships *Discovery* and *Morning*, from the pack ice of the Ross Sea. Four skulls and skins from this expedition are in the British Museum and there is also a stuffed animal which may account for another of the skins, as one is said to have been mounted. Wilson (1907) reported on this collection and gave measurements, colour, external description and the dental variation. The Scottish National Antarctic Expedition in the *Scotia*, 1902–04, collected the skeleton of a male animal and the skull of a female; both of the skulls are in the Royal Scottish Museum, Edinburgh. The osteology is described by Thomson (1915) and details of the catching of the animals by Wilton (1908). Thomson also mentions that the "respiratory apparatus" had been brought home, but there has been no further record of this nor has it ever been described.

The first French Antarctic Expedition in the *Français*, 1903–05, collected a single Ross seal skin from Booth Island (Trouessart, 1907), and the British Antarctic Expedition, 1907–09, in the *Nimrod* saw two young seals in the Ross Sea and killed one for food, although its identity was not realized until later (Shackleton, 1909). Anthony and Liouville (1920) describe the kidney of a seal caught by the second French Antarctic Expedition, 1908–10 in the *Pourquoi Pas?*, and there is also a skull in Paris from this voyage. The Australasian Antarctic Expedition in the *Aurora*, 1911–14, saw six Ross seals in January 1914 on the ice near the Haswell Islands (lat. 66° 32′S., long. 93°00′E.), off the Queen Mary coast. Although the report on the mammals from this expedition was never published, seals are mentioned by Mawson (1940, 1942), and at least three skulls and one skull and skeleton were collected and are now in museums in Sydney, Adelaide and Melbourne. A young seal was shot by Shackleton's party in the *Endurance* in the Weddell Sea in 1914, and Shackleton notes that "He was a young male and proved

* Although the material from this expedition is registered in Berlin as coming from the *Deutschland*, this was the ship of the second German South Polar Expedition of 1910–12 which did not go to Kaiser Wilhelm II Land. Presumably it was the *Gauss* which collected the Ross seal.

very good eating, but when dressed and minus the blubber made little more than a square meal for our twenty-eight men, with a few scraps for our breakfast and tea".

There are no further records of specimens being collected until the United States Antarctic Service Expedition, 1939–41. Four Ross seals were captured and an attempt was made to take a live animal to America, but it died after only a few days on board ship. The destination of these specimens is not recorded, but specimens of Weddell seals were taken for the U.S. National Museum (Perkins, 1945). The first international expedition to the Antarctic, the Norwegian-British-Swedish Antarctic Expedition in the *Norsel*, 1949–52, has so far been the most productive of Ross seal material; ten skulls, now in the British Museum, were collected from the Weddell Sea area.

Not every voyage south resulted in tangible evidence of Ross seals. Sometimes only written reports of sightings have been brought back and very many of these have never been published. Laws (1964), with access to many of these unpublished reports, has plotted the distribution of 120 sightings of Ross seals. They show a circumpolar distribution, relatively close to the Antarctic continent, with larger numbers—probably indicative of more observers—in the Weddell Sea. A single animal has been recorded from Heard Island (Béchervaise, 1965, 1967).

Until recently, there has been very little Ross seal material available, partly because the animal has not often been seen and partly because of the difficulties of collecting and of bringing home much more than the imperishable bones. Consequently, very little work has been done on the skeleton, and practically nothing on the soft parts or on the general biology and behaviour. The present study is based on a male and a female Ross seal which were secured by the British Antarctic Survey's relief vessel M.V. *Kista Dan* in January 1963. These specimens, which were probably the first complete carcases to reach this country, were delivered deep-frozen to the British Museum (Natural History) a few months later.

II. BRITISH ANTARCTIC SURVEY SPECIMENS

A. Locality

The female seal was caught on 25 January 1963 at lat. 64°22′S., long. 10°00′W., 450 miles north of Kapp Norvegia, Dronning Maud Land; the male was caught on the following day, slightly further south at lat. 65°43′S., long. 10°18′W. The ice cover at the time was five-tenths.

B. External Description

The general external features of the Ross seal have been recorded before (Racovitza, 1900; Hanson, 1902; Wilson, 1907; Brown, 1915) and it is unnecessary to repeat them. However, some parts of the animal have been incompletely described and these are now given in detail. The head and neck of the female carcase were distorted as it had been frozen while suspended from a hook, but the characteristic shape can be seen in the photographs of the male animal (Plate I) which were taken on board before it was frozen. The very short snout, short wide head and protuberant eyes are evident.

The female seal was dark silver-grey dorsally shading to silver-white ventrally. Laterally there were irregular thin longitudinal white streaks on the grey. This agrees with the general colour recorded for other specimens of the Ross seal, but it was difficult to manipulate the heavy frozen body to record colour details before dissection started. The frozen carcase of the male was distorted and blood-stained and therefore useless for notes on colour.

No scars were seen on the female seal. The male animal had three small scars, each about 6·5 cm. long at the anterior end of the body; one about 20·5 cm. dorsal to the insertion of the right fore flipper, and two nearly parallel scars on the ventral surface about 35·5 cm. from the chin.

The moustachial whiskers are few, short and almost smooth. On the female seal nineteen were counted on one side, including a single whisker remote from the others on a level with the posterior end of the nostril. The beading was hardly, if at all, appreciable, and the longest whisker measured 36 mm. No superciliary whiskers were present on either animal. A paper on the skin and hair of the male seal has been published by Polkey and Bonner (1966).

There have been conflicting reports about the size of the fore flippers (Plate IIa). Their large size was remarked on by Wilson (1907) and Brown (1915), for example, while both Racovitza (1900) and Barrett-

Hamilton (1901) said they were small. It is difficult to be precise about size as flippers are not easy to measure to exact points, and in the present instance no comparison has been made with the flippers of other species. The fore flipper nails (Plate IIb) are very small nodules, about 3 mm. long, almost hidden in the fur, and the soft tissue of the first (longest) digit extends some distance beyond the nail. The male seal has no nail on the fifth digit of either of its fore flippers. The osteology of this digit in this seal is mentioned later. The noticeable diminution in length of the digits from the first to the fifth is characteristic of southern phocids.

The hind flippers are of the shape typical of the southern phocids: the middle digit much shorter than the others so that the posterior border of the flipper is lunate, and the outer digits greatly expanded at their tips (Plate IIIa). The nails are of about the same size, or even smaller than those on the fore flipper, and are set back from the free edge. On the male seal the nails on digits 2 and 4 are very small but palpable nodules. On the other digits they are not palpable and their position was found only by shaving away the fur, when small pits in the skin could be seen. No obvious nail nodules could be found on these digits. The female seal has palpable nodules on all digits.

The tail is pointed (Plate IIIb), not rounded as in the Weddell seal. The connecting web of soft tissue extends from the ventral surface of the hind flipper down the side of the tail to its tip. The distance from the tip of the tail to the foremost part of the web when extended is 7 cm. in both animals.

Body measurements are given in Appendix A and weights in Appendix B.

C. Age

An attempt to estimate the age of the female seal was made by Professor H. R. Hewer using Laws' (1953) method. Longitudinal and transverse sections of the left lower canine tooth suggest that the age could be either 3 years or 7 years. Professor Hewer suggests that 3+ years is the most likely age as there are only three rings of cement, and although the dentine shows seven rings these could be at the rate of two rings a year, one indicating moulting and one breeding. The pulp cavity is still large and the tip of the root not completely closed.

D. Alimentary Canal

The alimentary canal is of the usual uncomplicated pinniped form. The total lengths, from the upper end of the oesophagus to the anus were 13·96 m. for the female, and 10·64 m. for the male. No caecum was seen, although the junction of small and large intestines was noted from the change in character of the wall.

E. Food

In the female seal the softer stomach contents were finely comminuted and no large fragments of flesh were found. There were no fish scales or other evidence of fish having been eaten. Apart from cephalopod beaks and eyes, which will be noted presently, the stomach contents were bright green in colour and included strips of thin tough tissue appearing at first sight to be of an algal nature. These were taken to the Botanical Department of the British Museum (Natural History) for identification, but they were rejected as not being of plant structure at all. They were then sent to Dr. Malcolm Clarke of the National Institute of Oceanography, who identified them as battered fragments of squid pens. By means of a spectral absorption curve, the green coloration was found to be not chlorophyll. It had minute traces of copper and rather more iron. Hanson (1902) noted that two of the Ross seals that he had caught had "sea-weed" and "vegetable stuff" in their stomachs; it is possible that this, too, was of cephalopod origin.

Cephalopod beaks are exceedingly difficult to identify, and it is probably for this reason that no precise determination has been attempted although most Ross seal stomach contents have contained them. Dr. Malcolm Clarke is working on this problem and has been able to identify, to a certain extent, the beaks from the present animal. A matching upper and lower beak are from *Moroteuthis* sp., the rostral length indicating a squid of about 7 kg. weight with a dorsal mantle length of about 70 cm. Another pair of beaks is from another species of Onychoteuthid of about 370 g. The rest are from two œgopsid species, at present not further identifiable. A very rough estimate of their weight suggests that one species ranges 60–400 g. and the other 60–120 g. There is at the moment no direct evidence as to whether the Ross seal can swallow a squid of the size of the *Moroteuthis* whole, or has to tear it up first. Barrett-Hamilton (1901) says that "It feeds exclusively on large cephalopods", and Brown (1915) that "A large cephalopod, over 6 feet in length, was captured in Scotia Bay in 1904 at the Argentine Meteorological

Station, which from its beak appeared to be of the same species as that on which the Ross Seal feeds". There is, therefore, a certain amount of evidence that the Ross seal feeds on cephalopods of a larger size than do other seals, and some aspects of its anatomy, mentioned later, seem to confirm this. Octopus, amphipods, euphausians and fish have also been recorded as Ross seal food.

No identifiable food material was found in the gut of the male seal, except for some pinkish substance in the intestine that could have been cephalopod flesh.

F. Parasites

External. No external parasites or nasal mites were found on either animal.

Internal. In the female seal a few roundworms were found in the stomach, but not in the intestine, and tapeworms in the stomach and upper regions (anterior 3 m.) of the intestine. The roundworms have been identified as *Porrocaecum decipiens* (Krabbe, 1878), and the tapeworms as *Glandicephalus antarcticus* (Baird, 1853) from the stomach and intestine, and *Diphyllobothrium wilsoni* (Shipley, 1907) from the intestine. The alimentary canal of the male seal had tapeworms in the 1·5–1·8 m. of gut immediately distal to the stomach, but not in other regions. These tapeworms were not in a sufficiently good state to be identified. No other parasites were found in this animal. The three genera identified have all previously been recorded from *Ommatophoca.*

G. Anatomy of the Head

The female Ross seal was shot in the left side of the neck, close to the back of the head. There was, therefore, damage to the muscles and bone in this area. To preserve the head for dissection it was removed from the body at about the middle of the neck. The combination of damage to the occipital and neck muscles by the bullet and by removal of the head, made it difficult to identify many of these muscles with certainty. The male seal was shot in the back of the head, the skull was fragmented and the soft tissues consequently severely damaged. Confirmation of the dissection of the head of the female seal was carried out as far as possible.

1. *Superficial muscles* (Fig. 1)

These, the sphincter colli primitivus and profundus, platysma and nuchal platysma are as illustrated and described in Huber (1934) for *Pagophilus* and *Pusa.* The frontalis arises from under cover of the orbicularis oculi, extends in a cranial direction for about an inch and the fibres are then lost in the blubber. Antero-posteriorly this muscle extends from the level of the anterior corner of the eye to that of the postorbital process of the zygomatic. The buccinator extends as a rather thin muscle from the external surface of the lower jaw below the teeth, round the angle of the mouth, and the fibres then merge with those of the orbicularis oculi.

2. *Eye*

The fibres of the orbicularis oculi are attached anteriorly to the antorbital tubercle of the maxilla and extend circularly round the palpebral fissure. Huber (1934) notes that the phocids he dissected lacked the diverging bundles of this muscle that he found at the posterior corner of the eye in *Zalophus*, but a well developed diverging bundle is found in *Ommatophoca*. The short superciliaris muscle is also attached to the maxillary tubercle.

The generic name *Ommatophoca* is based on the enormous orbits of this seal, but references to the eyes are confusing and contradictory. Barrett-Hamilton (1902) says "the eyes are large and protruding", but Trouessart (1907) says "the eyes are not large (in spite of the development of the orbits which inspired Gray to name the genus)", and Wilson (1907) also notes that "the eyes are not large". The confusion seems to have arisen because the distinction was not made between the palpebral fissure and the eyeball. The former is unremarkable in length (32 mm.), and is of the same order of size as in both *Halichoerus* (34 mm.) and *Zalophus* (24 mm.) in animals of comparable size.

The eyeball, however, is enormous, and apart from a normal amount of soft tissue round the periphery, it fits the orbit (Plate IV). The horizontal diameter of the eyeball is 60 mm., vertical diameter 57 mm., and axial diameter 55 mm.* These figures may be compared with similar ones for *Phoca vitulina* (35×37 mm., axis 35 mm.), *Pusa sibirica* (43×43 mm.) and *Zalophus* (39×39 mm.). In spite of the large size of

* These measurements were taken on the eye of the female, as those of the male were damaged. It is probable that the axial diameter is greater in life, as the eyeball had collapsed slightly during preservation.

the eyeball, the cornea, which is uniformly convex, is not of excessive size (vertical diameter 34 mm., horizontal 36 mm.); it is very much the same size as in other seals (*Phoca vitulina* 24×24 mm., *Pusa sibirica* 30×30 mm., *Zalophus* 30×25 mm.). An increase in the size of the hinder part of the eyeball (fundus) results in "an increase in the size of the image relative to the size of the eye, with a consequent increase in resolving power" (Walls, 1942). This is probably associated with the agility and manœuvrability of the Ross seal in pursuit of its prey in the water. The lens is 11 mm. in diameter.

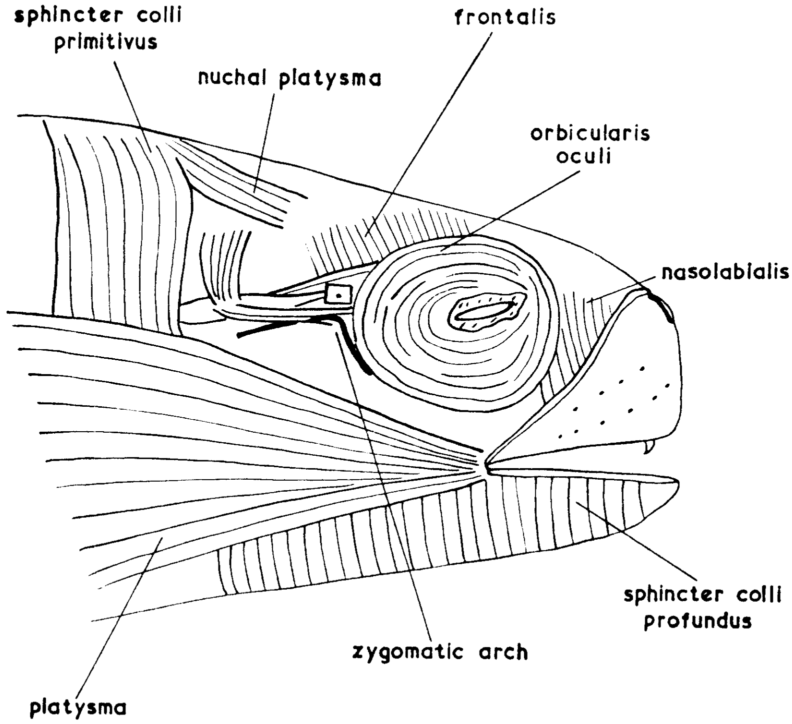


FIGURE 1

Lateral view of the head, with the blubber and most of the skin removed to show the superficial muscles.

Dr. Stuart Saunders* has kindly provided the following notes on the eye:

At the coronal equator of the eyeball the sclera is very much thinned in a belt about 5 mm. wide. Elsewhere the sclera is 2·3 mm. thick (though slightly thinner at the optic nerve exit), but here it is less than 0·5 mm. thick and easily compressible. It appears that it is the inner layers of the sclera that are deficient, rather than the outer layers. Similar scleral thinning has been described by Wilson (1865) and Hey (1790) in what were probably *Phoca vitulina*, and it also occurs, but is much less well marked, in *Zalophus*.

The four recti and the two oblique muscles are attached just anterior to the thinned belt of the sclera. The four bellies of the retractor bulbae are staggered between the recti and attach to the sclera 15–20 mm. in front of the posterior pole of the eyeball, i.e. well behind the coronal equator.

The nictitating membrane is well developed and when at rest, in the preserved state, covers the lower medial third of the cornea. It is attached to the medial rim of the orbit by a strong ligamentous band containing a bar of stiffening cartilage about half an inch long. This occurs in other seals (Walls, 1942).

Because of the thinning of the sclera, the anterior and posterior halves of the eyeball can presumably move independently of each other. This may allow the optic axis to be lengthened or shortened as part of the mechanism of accommodation in air and water. When the anterior half of the eyeball is retracted the lens is pushed relatively further forward, and the ciliary contraction will render the lens more nearly spherical than it is at rest. The configuration of the eye thus

* Department of Anatomy, London Hospital Medical College.

approximates to that of fishes, in which the lens is far forward to gather the maximum possible light, and is spherical or nearly so.

3. *Nose*

The maxillo-nasolabialis was not found. The nasolabialis does not, in *Ommatophoca*, have nearly such an extensive origin as is indicated in Huber (1934) and Brazier Howell (1929) for *Pusa* and *Zalophus* in which it extends to "near the middorsum of the rostrum" with, in *Zalophus*, connections with the frontalis. In *Ommatophoca* (Fig. 2) it is attached to the nasal cartilage and to the premaxillae. The posterior

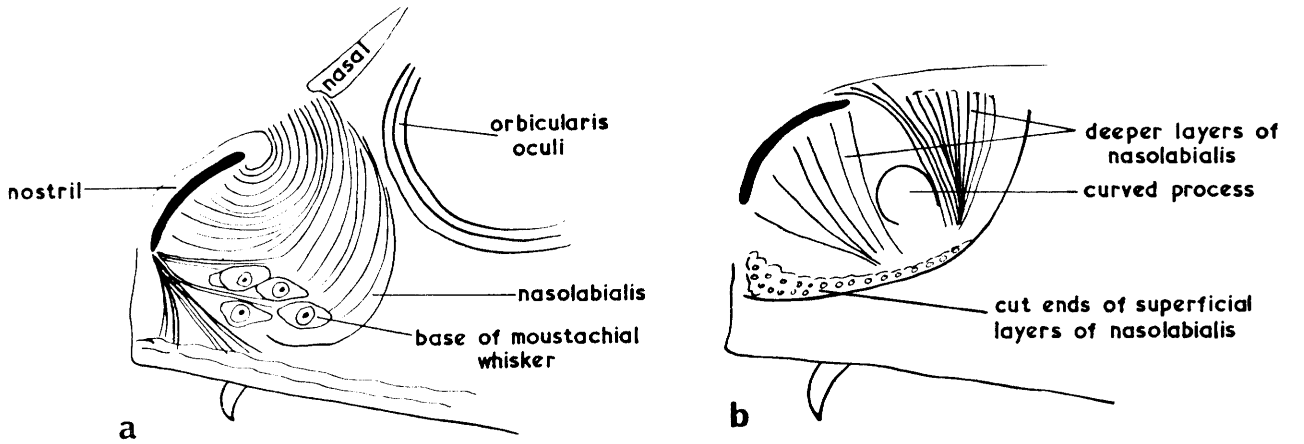


FIGURE 2

a. The distribution of the nasolabialis muscle; lateral view of the left side of the snout.
b. The deeper layers of the nasolabialis from the side of the nostril and the side of the lateral cartilage. The cut ends of the superficial fibres of the nasolabialis are indicated, and also the tip of the cartilaginous curved process.

fibres originate from the nasal cartilage laterally, just anterior to the latter's attachment to the nasals and maxillae, and curve round to be inserted into the moustachial pad; the anterior fibres curve more abruptly and are inserted into the nasal pad. Because of the rather small development of the moustachial pad in the Ross seal, a distinction may be made between it and the lateral wall of the nostril with its fibrous and muscular tissues which forms a nasal pad. Ventral to the nasal pad muscle fibres go vertically from it to the horizontal parts of the premaxillae.

The nasal cartilage (Fig. 3a) is attached to the anterior end of the nasal bones, to that small part of the maxilla between the nasals and the premaxilla, and to the medial surface of the vertical part of the

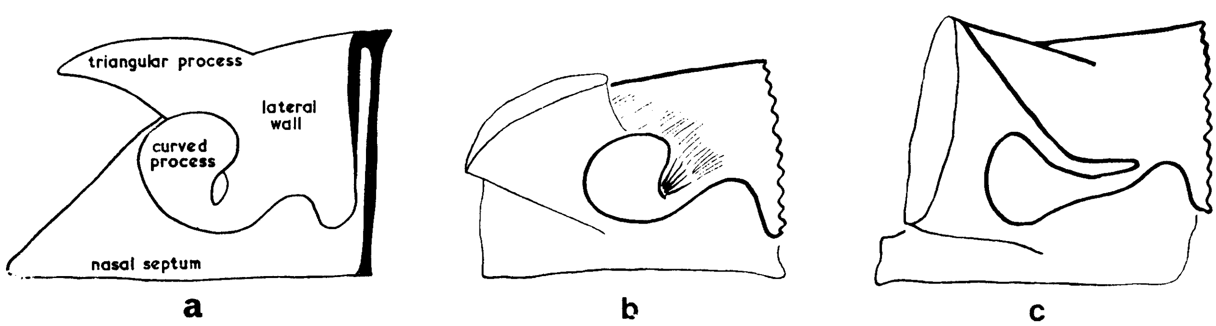
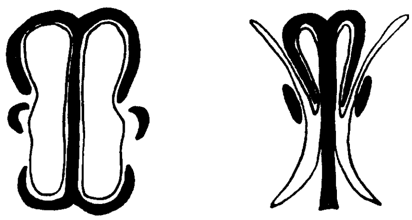


FIGURE 3

a. The nasal cartilage showing lateral wall, triangular and curved processes, and beneath them the cartilaginous nasal septum. Posteriorly, the thick black lines show the cut surface of the nasal septum and the attachment of the lateral cartilage to the premaxilla. Both these cut surfaces are indicated almost at right angles to their normal orientation to show their relationship.
b. The nasal cartilage with the soft tissue of the nostril in its normal position between the triangular and curved processes.
c. The artificially expanded nostril.

premaxilla. The cartilage, while recognizably of the same general form as that of *P. vitulina*, has certain differences, possibly because of the combination in the Ross seal of an exceptionally short snout with the nostrils on the dorsal surface. The simple nasal passage found in *Phoca* (Fig. 4) has here become more complicated, possibly for the same reasons, but the result is a much tighter closure of the nostrils and a more efficient safeguard against the entry of water.

The dorsal expansion of the cartilaginous nasal septum immediately anterior to the nasal bones is flat and triangular with its base along the free edge of the nasals. Laterally, it curves sharply downwards on each side to form the lateral walls. These are pinched in so that they lie parallel to and close up against the nasal septum, and are produced forwards into an upper, long, triangular process and a lower curved process.



a b

FIGURE 4

Diagrammatic transverse sections of the snouts of a. *Phoca vitulina*, b. *Ommatophoca rossi* to show the elaboration of the nasal passage in *O. rossi*. The cartilage is indicated by the thick black lines.

In the resting position the nostril is in immediate communication with a lateral triangular part of the nasal cavity which is supported laterally by the fibrous tissue of the nasal pad. This lateral cavity lies between the pad and the triangular process which is flattened against the nasal septum. The curved process supports the ventral corner of this part of the nasal cavity which, because of the position of the triangular process, has little if any communication with the main nasal cavity. In fact, when the nostril is shut (Fig. 3b) the two sides of this part of the nasal cavity are closely pressed together so that the cavity is obliterated. It is closed by the pressure on it of the nasal pad, which is also pressing on the triangular process, thus creating double security against the entry of water. Contraction of the nasolabialis would pull the nasal pad laterally and also lift the triangular process, both parts of the movement being necessary to open the air passage (Fig. 3c).

4. *Ear*

The external opening of the auditory meatus is extremely small. It is not obvious in the complete head, and its presence causes no disturbance of the pelage. The opening will just admit a seeker and is about 1 mm. in diameter. A very small external opening (2 mm.) is also noted in *Hydrurga* (Murphy, 1913).

In relation to the skull the external opening lies just dorsal to the postorbital process of the jugal (Plate IV), and the auditory meatus runs along the dorsal surface of the squamosal part of the zygomatic. Between the outside of the head and the tympanic membrane the auditory meatus may be divided into two distinct parts. From the external aperture, the first 4·5 cm. of the tube is of soft tissue only, unsupported by cartilage, and lined by dark skin bearing short hairs. Its external diameter is 5 mm., and the diameter of the lumen 2 mm. For the remaining 3·5 cm. the meatus is encased in hard, brittle, well vascularized cartilage which is attached to the rim of the bony auditory meatus on the skull. The external diameter of the cartilaginous part is about 1 cm. Although simpler in form, the ear cartilage is recognizably of the same general shape as that of *P. vitulina* figured by Boas (1912).

It is the anterior, soft part of the auditory meatus that lies directly under the blubber. The skin surrounding the external opening is *c.* 6 mm. thick, and the auditory meatus slopes backwards and inwards so that at about 3–4 cm. along its length it lies under 1·5 cm. of blubber (i.e. about 2 cm. below the surface). The junction between the soft part and the rigid cartilage-supported part of the auditory meatus comes approximately where the tube traverses the junction between the blubber envelope and the general musculature of the head.

In *Phoca*, the lining of the auditory meatus lies directly internal to the cartilage. A longitudinal section of the auditory meatus of *Ommatophoca* (Fig. 5a), shows that there is a considerable amount of dark brownish-red tissue lying between the cartilage and the lining of the tube. Distally, where there is no cartilage, this tissue is absent. Although the thickness of the cartilage varies slightly, at one representative point on the section the outer cartilaginous wall is 2 mm. thick, the lumen of the auditory meatus is 2 mm. in diameter, and between the tube and the cartilage is about 2 mm. of the dark tissue. A transverse section of the tube (Plate Va) shows the ceruminous glands with their ducts opening into the central lumen, but the main tissue between the lumen and the cartilage is of collagenous fibres supporting numerous veins. This venous tissue extends almost as far as the tympanic membrane, separated from it only by the very narrow expansion of the auditory meatus (Fig. 5b).

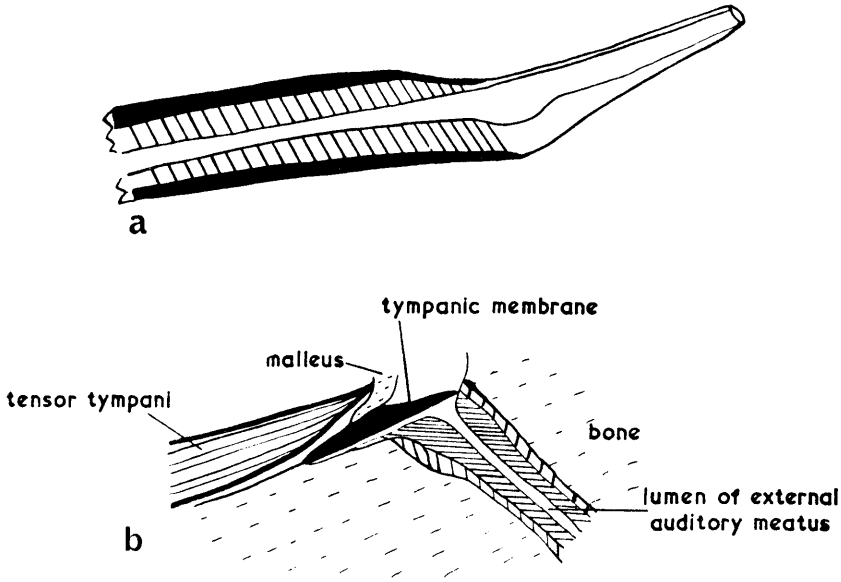


FIGURE 5

a. Sagittal section of the auditory meatus. The solid black is cartilage, hatching indicates venous tissue.
b. Diagram of a section to show the meeting of the auditory meatus and tympanic membrane (shown in solid black). In the middle ear cavity the tip of the malleus and the tensor tympani muscle are shown. The cartilage of the auditory meatus is shown widely hatched, the venous tissue finely hatched.

The ear muscles present are as those found in *Phoca*; the only difference is in their position and that is consequent on the low position of the zygomatic arch. Because of this, the auditory meatus is more nearly horizontal in *Ommatophoca* so that the auricularis posterior, instead of being truly posterior and horizontal, is vertical (Fig. 6). The internal and external protractors and the retractor are all approximately similar to those in *Phoca*, being attached to the distal part of the cartilage of the tube, but whereas this is only just under the skin in *Phoca*, in *Ommatophoca* it is half-way along the length of the auditory meatus and about 2 cm. below the surface.

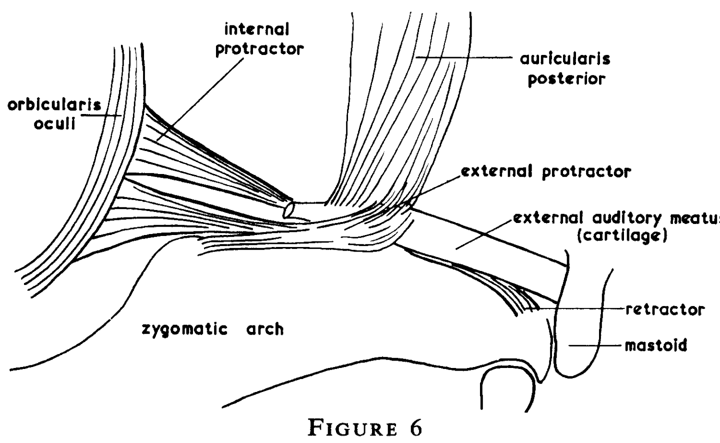


FIGURE 6

Ear muscles. The anterior part of the auditory meatus has been removed.

The auricularis posterior is a flat ribbon-shaped muscle (*c.* 9 × 3 cm.) lying spread on the lateral surface of the temporal muscle and covered by the platysma. Its attachment is to the lateral surface of the auditory meatus at the level of, and slightly anterior to that of the external protractor. The latter, from its insertion on the auditory meatus in close association with that of the auricularis posterior, passes forwards ventral to the tube, may be partly attached to the fibrous tissue over the postorbital process of the jugal, and then curves ventrally to fan out under the orbicularis oculi. The internal protractor, from its attachment on the medial surface of the tube, passes dorsally and also fans out under the orbicularis oculi. The retractor extends from the medial side of the tube, posteriorly, parallel to the tube, and is attached to the skull just dorsal to the glenoid cavity.

From the positions of the muscles in *Phoca* it is not easy to see how they can be of much use in closing the external opening of the auditory meatus when the animal is under water, though the main closure of the tube must be by water pressure on the side of the head. It is even less likely that the Ross seal ear muscles, so far back along the tube, can play any part in regulating the aperture of the ear-hole or the tube, but their contraction may slightly alter the position or tension of the tube.

The tympanic membrane is oval and faces antero-laterally, as does that of *Phoca*. Its lateral surface is at an angle of 125° to the long axis of the skull; the long diameter is 11 mm., and the short (dorso-ventral) diameter 6 mm.

The shape of the tympanic bulla is approximately triangular in ventral aspect. An irregular ventral "lid" was removed from the bulla (Fig. 7a) in order to see the middle ear cavity, and it was noticed that there was considerable variation in the thickness of the bone (Fig. 7b). The thickest part of the bulla wall was that forming the most ventral projection, which was 12 mm. thick. The medial wall, and the antero-

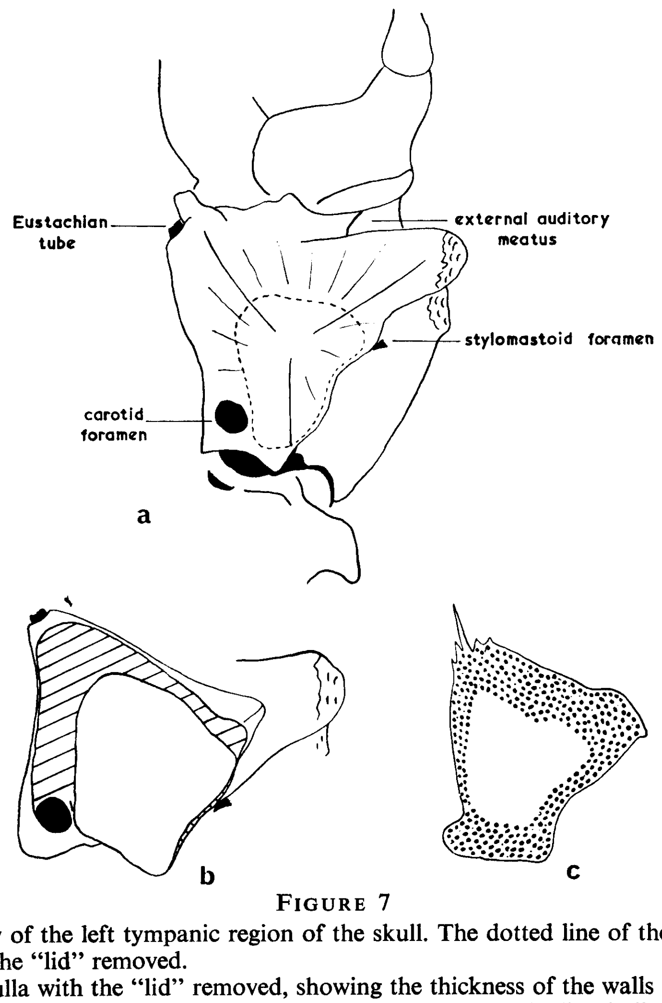


FIGURE 7

a. Ventral view of the left tympanic region of the skull. The dotted line of the bulla indicates the area of the "lid" removed.
b. The same bulla with the "lid" removed, showing the thickness of the walls (hatched).
c. Ventral view of the middle ear lining of the same bulla. The shading indicates the areas of greatest vascularity.

medial corner (ventral to the Eustachian tube) were also about 12 mm. thick, and the antero-lateral wall was 4 mm. and the postero-lateral wall 1–2 mm. Although not part of the middle ear, the great thickness of solid bone (3 cm.) of the lateral expansion of the squamosal dorsal to the bony external auditory meatus may also be mentioned. Comparison with a limited number of Weddell, crabeater and leopard seal skulls suggests that, with the exception of the ventral region, the dimensions noted above for other parts of the bulla walls in the Ross seal are approximately similar in all four genera. The ventral part of the wall, however, is thinner (*c.* 3–6 mm.) in the Weddell and crabeater seals, and thicker (*c.* 12 mm.) in the leopard and Ross seals.

In this connection, it is relevant to note that van der Klaauw (1931) says "... the other extreme condition, [is] that of the very dense and thick bulla. This condition is due to aquatic life. Further the Otariidae show a thin walled bulla; among the Phocidae the less highly organized species show also a thin walled bulla which, however, is already more dense than that in the Otariidae, while the more specialized Phocidae show a bulla which resembles that of the Cetacea".

Careful removal of the "lid" of the bulla exposes the lining of the middle ear; the lining lies external to the ossicles and middle ear muscles so that these cannot be seen until it is removed. The thickness of the lining varies. Ventrally, internal to the thickest part of the bone, it is thin, but the rest shows signs of a vascular thickening of the wall particularly in that area which lies over and just posterior to the cochlea (Fig. 7c).

The middle ear lining of *P. vitulina* also shows this vascular thickening (Plate Vb), a section through it exposing the closely packed veins in the tissue. A section through the thick region of the Ross seal ear lining (Plate Vd) shows that the vascularity has increased to such an extent that in some places there is a large venous sinus instead of a mass of vessels. The thinner parts of the lining also show this amalgamation of veins (Plate Vc). The venous plexus of the middle ear lining of *P. vitulina* was described by Tandler in 1899, but since that time no further mention has been made of it in this or any other seal, although it is quite probable that it exists at least in all phocids.

Ear ossicles of many mammals have been very fully described and figured by Doran (1878), and of the Antarctic seals he had seen those of *Lobodon* and *Hydrurga*, and also *Mirounga*. The mallei of all four Antarctic seals are approximately similar in general dimensions (Fig. 8), and have a shorter thicker neck and a less obtuse angle between the neck and the manubrium than is found in the Phocinae. In *Leptonychotes*, the arrangement of the two circular cup-shaped articular facets, lying side by side and occupying about half the head, is very similar to that in *Halichoerus* (as a representative of the Phocinae), while in *Hydrurga* and *Lobodon* the facets are larger in proportion to the size of the head. In *Ommatophoca*, the articulating surface occupies almost the entire head and the discreteness of the two facets is not obvious, the dividing ridge being absent. The single large facet is saddle-shaped, being deeply concave parallel to the line of the neck, and slightly convex at right angles to it. The anterior face of the head is roughened and excavated in all four animals, but appears to be least so in *Ommatophoca*. The processus gracilis springs from the anterior surface of the neck; it is very small in *Ommatophoca* but slightly larger in the other three seals. The tip of the manubrium is curved laterally in *Lobodon* and anteriorly in *Ommatophoca*.

Doran noted the shape of the incus of *M. leonina* with its "immense development of the posterior part of the body, which leans over to the outer side of the crura to an extraordinary degree". The posterior part of the body is not so bulky in the four other Antarctic seals. The groove interior to the articular facets is most marked in *Lobodon*, in which the appearance is as if the two sides of the body have been curved towards each other and an articular surface placed on each. In *Leptonychotes* and *Hydrurga* the groove has become a depression, and in *Ommatophoca* it is a circular dimple. The articular facets mirror those on the malleus, being single in *Ommatophoca* and double in the others. The processus longus is, when compared with that in the Phocinae, long and slender, approximately circular in cross-section and with a sharply recurved tip. The processus brevis is short and conical.

In both *Lobodon* and *Leptonychotes* the stapes is delicate, with very flattened crura enclosing a small foramen. The head is small and circular, the base larger, oval and concave along its long axis. Doran notes that the stapes of *Hydrurga* also has flattened crura, and that in *Lobodon* the foramen is not invariably present. Compared with that of *Lobodon* and *Leptonychotes*, the stapes of *Ommatophoca* is longer, considerably more stoutly built, and not flattened. The foramen is very small and does not always perforate the bone.

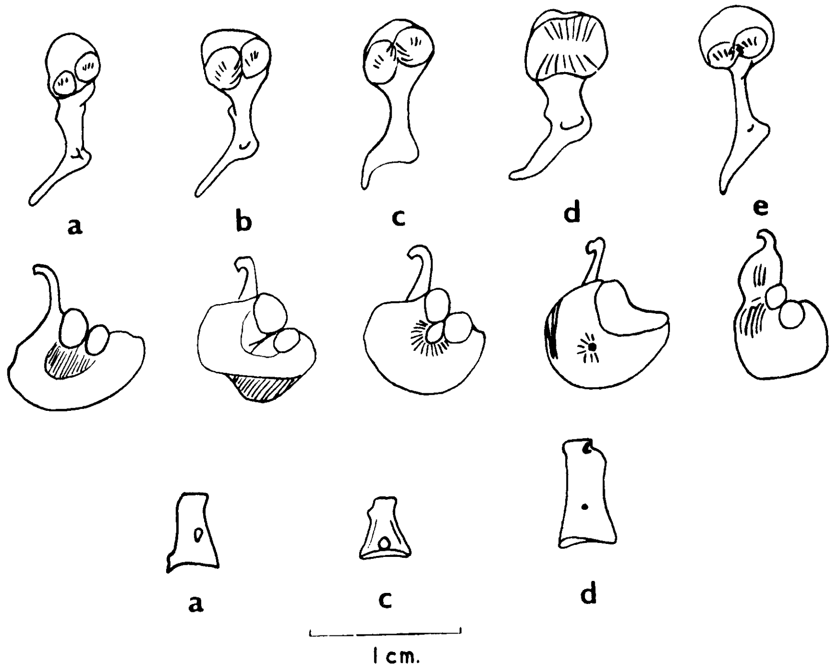


FIGURE 8

Top row-malleus, middle row-incus, lower row-stapes of A—*Leptonychotes*, B—*Hydrurga*, C—*Lobodon*, D—*Ommatophoca*, E—*Halichoerus*.
Each malleus is arranged with the long axis of the neck vertical. Each incus is arranged with the long process vertical; the short process is then at right angles to, and below the plane of the paper.

In all phocids examined, both malleus and incus have their two articular facets approximately at right angles to each other. A snug right-angled incudo-malleolar articulation is thus formed. Little is known about the ultra-sounds emitted by seals, and sounds of low frequency (usually below 16 kc./sec.) are so far the only ones to have been recorded, although Møhl (1964) has noted that *P. vitulina* can hear frequencies as high as 160 kc./sec. The work of Henson (1961) on bats is perhaps relevant. He notes that the articular facets of the malleus meet at a more acute angle (90–100°), forming a firmer joint, in those Microchiropterans that use ultra-sounds of an upper frequency above 50 kc./sec. He also notes that the tensor tympani muscle is better developed in the Microchiroptera than it is in other mammals of similar body size which do not use ultra-sounds. The combination, in Microchiroptera, of delicate ossicles of some rigidity (because of the osseous attachment of the lamella of the malleus to the tympanic) together with a discrete incudal ligament and a well developed tensor tympani, seems advantageous for the transfer of ultrasonic vibrations.

Compared with bats, the sounds so far recorded as being emitted by seals are very low, the ossicles are not attached rigidly to the tympanic, and are not at all delicate. Doran (1878) notes their dense consistency and that in the Phocidae they are absolutely and proportionally very large. The shape of the incudo-malleolar articulation, however, suggests perhaps that phocids may have greater acuteness of hearing than has hitherto been suspected. The greater size and density of the ossicles may be some compensation for the lack of rigid attachments. The Ross seal, with its slightly differently shaped articulation and very well developed tensor tympani may, in addition to its other specializations, have potentials of hearing that are not yet understood.

Although it has been compared only with that of *P. vitulina*, the tensor tympani muscle of *Ommatophoca* appears to be of large size. Its greatest length is 20 mm. and greatest width 10 mm., compared with 10×6 mm. in *Phoca*. It is a stout, red, bulbous muscle the tendon of which is not easily seen, while in *Phoca* it is a pale, much thinner muscle with an easily visible tendon. The stapedius muscle was not found.

Outside the bony tympanic bulla the Eustachian tube is approximately 2·5 cm. long, and lies against the posterior part of the medial surface of the pterygoid. A section taken at about the middle of its length shows that the lumen of the tube is about 2 mm. in diameter, is dorso-ventrally flattened, and is separated from the pterygoid bone only by the thin fibrous dorsal wall. The ventral wall of the tube is much thicker (4 mm.), very stiff, and composed of collagenous fibrous tissue (Plate VIa). No cartilage could be seen in it. The levator palati muscle is attached to the lateral surface of the ventral wall.

Zuckerkandl (1896) has described the Eustachian tube of *P. vitulina* from sections taken at varying points along its length. From one at about the middle of its length he notes that the cartilaginous support has increased in size so that it forms the dorsal wall of the tube. A section of the Eustachian tube of a young *P. vitulina*, taken from just anterior to the tympanic bulla (Plate VIb), shows the lumen of the tube lying lateral to the supporting tissue which is composed mainly of collagenous tissue surrounding a small amount of cartilage. In *Ommatophoca*, as noted above, the lumen is dorsal to the main fibrous support and remains so right up to the tympanic bulla.

5. *Mouth cavity*

With one side of the lower jaw removed and the associated muscles cut, the entire mouth cavity can be seen. The most remarkable feature about this cavity is the length of the palate (Plate VIIa), which from the posterior surface of the incisors is 245 mm. (90·7 per cent of the condylobasal length), its posterior end being in line with the occipital condyles. The mouth of a common seal shows the more usual condition that is found in most mammals, i.e. the posterior end of the palate is in line with the glenoid cavity (Plate VIIb). The length of the *Phoca* palate is 105 mm. (58·3 per cent of condylobasal length). In the Ross seal the hard palate is short, so it is the soft palate that forms the greater part of the palate length (63·3 per cent; cf. 38·1 per cent in *Phoca*).

The Ross seal soft palate is very muscular, and its surface is very wrinkled. In the mid line, 5 cm. from the hard palate, the thickness of muscle is 1·5 cm., and at 8 cm. from the hard palate it is 1 cm. thick. The wrinkles are particularly fine and numerous along the posterior edge of the soft palate, and in the last centimetre there are few, if any, muscle fibres. It seems reasonable to suppose from this structure of the soft palate that it is very expansible. Certainly, the wide and deep post-palatal area of the skull would allow upward expansion, and it was Racovitza (1900) who suggested that the palate could be distended with air and used like a bagpipe: "Son larynx fortement gonflé constitue une caisse de résonnance et le voile du palais très développé, distendu par de l'air, constitue à l'animal une sorte de cornemuse."

In the two preserved Ross seal heads the tip of the tongue was on a level with the fourth cheek tooth in the female, and level with the first cheek tooth in the male. In a preserved *Phoca* head the tip of the tongue was level with the canine, and the rather caudal position of the Ross seal tongue could be due to post-mortem changes.

The epiglottis and tongue have maintained their normal position relative to the posterior end of the soft palate, and consequently give the impression that they have been pushed backwards. The Ross seal tongue appears to be short and wide, but in actual length along its free lateral edge (85 mm.) it is only a little shorter, relative to the length of the skull, than that of *Phoca*. The length of the tongue of *Phoca* is 65 mm., the proportions to condylobasal length are 31·5 per cent in *Ommatophoca*, and 36·1 per cent in *Phoca*. The surface of the Ross seal tongue shows far fewer papillae than that of *Phoca*.

6. *Epiglottis*

The epiglottis is not of the usual inconspicuous pinniped form. It is a well developed structure, approximately 3 cm. in greatest antero-posterior length, and 4·5 cm. in greatest width. Its most characteristic feature, and one that has not previously been mentioned for any other pinniped epiglottis, is the great size of the lateral epiglottic folds (Plate VIII). These are very thin, almost transparent, hemispherical flaps, each approximately 1·5 cm. wide, that in the preserved specimens were folded flat on the dorsal surface of the epiglottis (Fig. 9).

7. *Extrinsic tongue muscles*

The anterior origin of the genioglossus (Fig. 10) is on the inner surface of the lower jaw, dorsal to the origins of the mylohyoid and geniohyoid. It is a thick muscle (*c.* 1·5 cm. mid ventrally) and the fibres go from the jaw posteriorly and into the substance of the tongue. Some posterior fibres are inserted on the ceratohyal and cerato-basihyal junction, and go forwards into the tongue.

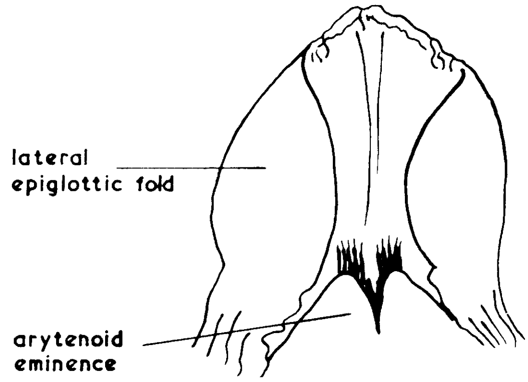


FIGURE 9
Diagram of the epiglottis showing the large size of the lateral epiglottic folds.

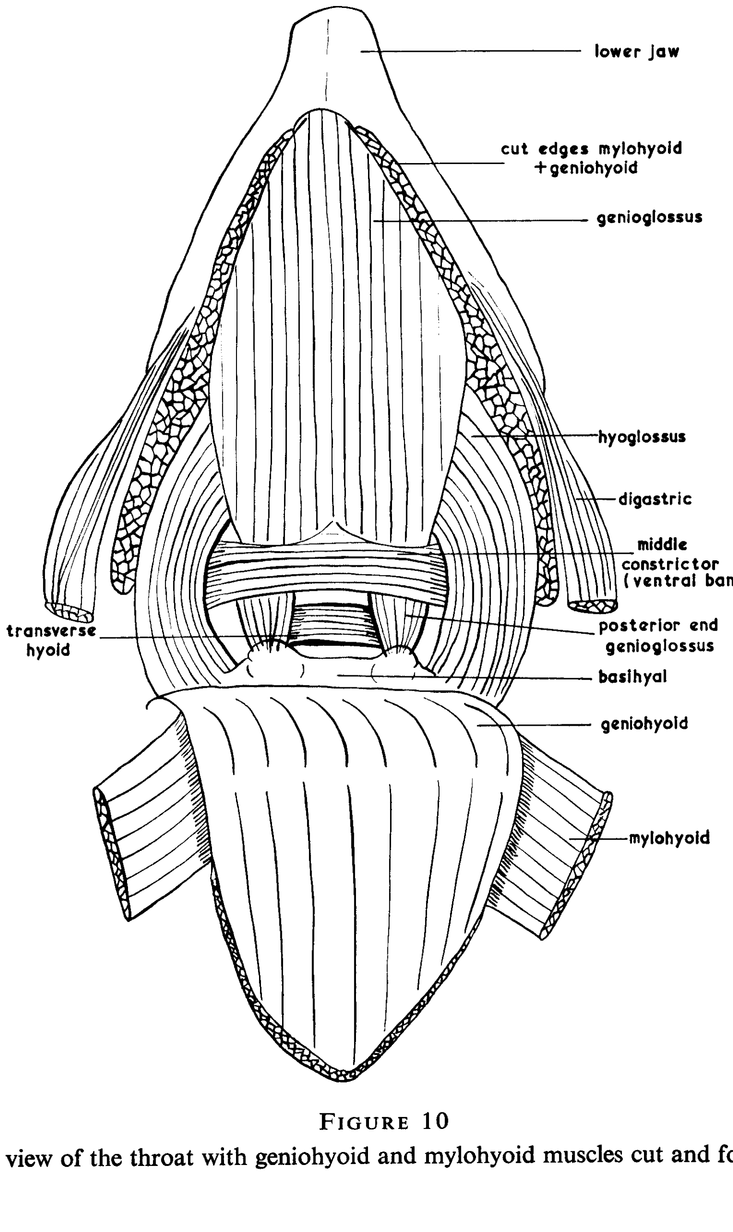


FIGURE 10
Ventral view of the throat with geniohyoid and mylohyoid muscles cut and folded back.

The hyoglossus (Fig. 11) is a bulky muscle going along the ventral and most lateral surfaces of the tongue. The ventral parts of the muscle are attached to the anterior face of the thyrohyal tubercle*; the more lateral fibres spread out posteriorly over the middle constrictor. The hyoglossus is, laterally, the outermost muscle of the tongue, and lies lateral to the styloglossus. Miller (1888) describes the origin of the hyoglossus in *Phoca* as "from the thyro-hyal, slightly from the basi-hyal and cerato-hyal". In the Ross seal it is separated from the ceratohyal by the transverse ventral part of the middle constrictor and the posterior part of the genioglossus; it does not approach the basihyal, and its only connection with the hyoid is to the thyrohyal tubercle.

The styloglossus is a much less obvious muscle than in *Phoca*. It arises from the anterior surface of the tympanohyal tube and passes almost immediately into the substance of the tongue, medial to the hyoglossus. It does not spread out over the lateral surface of the tongue as in *Phoca.*

8. *Extrinsic hyoid muscles*

The mylohyoid is as described by Howell (1929). It arises from the medial surface of the lower jaw and is inserted into a medial raphe and on to the basihyal. Near the basihyal its fibres become closely inter-

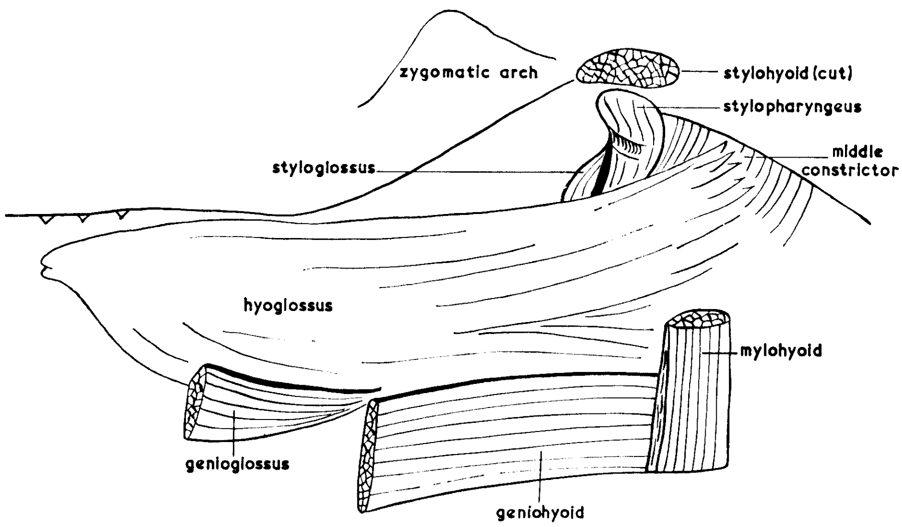


FIGURE 11

Ventro-lateral view of the tongue. The digastric muscle and lower jaw have been removed to show the positions of the hyoglossus, styloglossus, stylopharyngeus and tympanohyal tube (the last in solid black). The groove across the stylopharyngeus for the external carotid artery is indicated.

mingled with those of the stylohyoid. The mylohyoid forms a thick sling (Fig. 12) between the two rami of the lower jaw, mid ventrally the muscle is 1·5 cm. thick, and as it passes under the digastric and nears its attachment to the lower jaw it is 2·5 cm. thick.

The geniohyoid is a wide, thick muscle running from either side of the symphysis of the lower jaw to the basihyal. Midway along its length the muscle is 12 cm. from side to side, and 2 cm. thick.

The stylohyoid is a stout muscle lying immediately lateral to the digastric. It arises from the bone posterior and ventral to the external auditory meatus, and ventrally it merges with the posterior end of the mylohoid near the latter's attachment to the hyoid, the two muscles being indistinguishable in this region. In the Ross seal the stylohyoid is not the "narrow transverse band" that Miller describes for *Phoca*, nor the "very thin slip" that Howell found in *Pusa*, but a large, obviously powerful muscle.

Howell (1928, p. 46) notes that in *Pusa* there was a slip of the stylohyoid deep to the digastric, which disappeared in the neighbouring tissue and could only be found on one side. In the female Ross seal there is a slip in a similar position (Fig. 15). It is attached to the posterior surface of the glenoid cavity, just anterior to the main mass of the stylohyoid. It lies lateral to the masseter and deep to the digastric but it was not possible to trace it more than 3–4 cm.

* See p. 17.

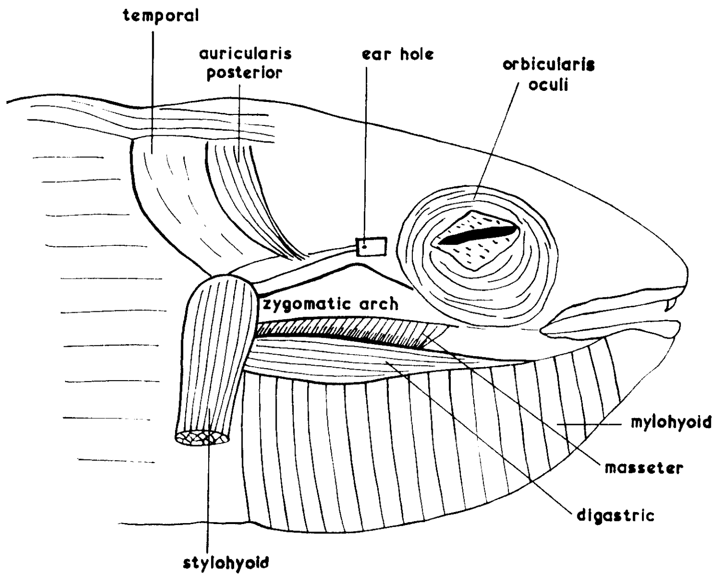


FIGURE 12
Right side of the head after the superficial muscles have been removed.

9. *Hyoid*

This is a very stout structure, consisting of paired ceratohyals and epihyals in the anterior cornua, paired thyrohyals in the posterior cornua, and a single basihyal (Fig. 13).

The basihyal is a stout bar 4·5 cm. in overall length, with a rounded dorsal surface and a transverse keel along its ventral surface. Anteriorly, on each end, are synovial joints with the ceratohyals. The latter bones are approximately 4·5 cm. long, flattened dorso-ventrally at the articulation with the basihyal, but becoming sub-cylindrical rods at their dorsal ends. The epihyals are slender tapering rods 6·5 cm. long, the 2 cm. adjacent to the ceratohyal being ossified, the rest cartilaginous. Approximately 6 mm. of the tip of the cartilage is bent over and lies against the shaft. The thyrohyal is 4 cm. long. It has a dorso-ventrally elongated synovial joint with the basihyal, and immediately posterior to this is a pronounced ventral process, apparently previously undescribed, and here named the thyrohyal tubercle. Posteriorly the bone is triangular in section and its postero-medial tip articulates with the thyroid cartilage. The thyrohyal tubercle gives attachment on its anterior face to part of the hyoglossus, and on its posterior face to part of the thyrohyoid (Fig. 18a).

The articulation of the hyoid with the skull is not in the usual way, although there is an apparent tympanohyal ligament in the normal position from the tympanohyal pit in the bulla extending caudal to the sternomastoid. The "ligament" in the Ross seal is actually a fibrous tube. There is an outer, thicker coat to which the stylopharyngeus is attached on its posterior surface and the styloglossus on its anterior surface; a thin, inner coat surrounds the upper end of the epihyal (Fig. 14a). This fibrous tympanohyal tube is attached to the bony part of the epihyal and to the epi-ceratohyal joint and, at its dorsal end, to the tympanohyal pit. Within the smooth inner tube the epihyal has a certain range of up and down movement, but two fibrous stays (Fig. 14b and c) come from the tube to the shaft.

It has not been possible to compare this hyoid with that of *Lobodon* or *Leptonychotes*, but it shows considerable similarities to that of *Hydrurga*, particularly in the development of the thyrohyal tubercle.

10. *Intrinsic hyoid muscles*

The transverse hyoid muscle lies transversely between the posterior ends of the ceratohyals—the fibres parallel to and just anterior to the basihyal. These are the same attachments as Sisson (1930, p. 264) records for this muscle in the horse, although he notes that it is not present in the dog. Miller (1888) does not mention it, nor was it seen a in recently dissected *P. vitulina.*

The ceratohyoid (Fig. 14d) is a stout, harp-shaped muscle, its fibres running parallel to the longitudinal axis of the tongue. It is attached at its anterior end to all of the posterior edge of the ceratohyal and the

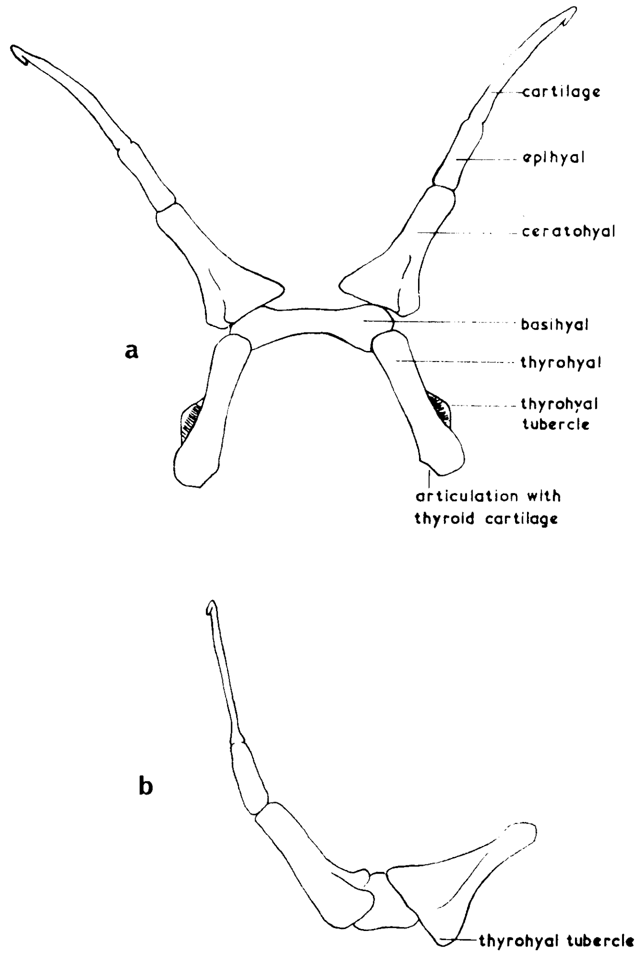


FIGURE 13
Hyoid.
a. Dorsal view.
b. Lateral view, left side.

bony part of the epihyal, at its posterior end to the anterior edge of the thyrohyal and particularly to the junction of the thyrohyal with the thyroid cartilage (Fig. 18a). Its action would be to help pull the hyoid and root of the tongue back. In *Phoca* it is not nearly such a powerful muscle and the fibres are at more of an angle to the tongue.

11. *Muscles of the soft palate and pharynx*

The levator palati is a triangular muscle lying chiefly on the medial surface of the pterygoid, but just extending on to its lateral face. Its postero-medial edge arises from the tympanic bulla, lateral to the insertion of the tensor palati, and from the lateral surface of the ventral wall of the Eustachian tube. The antero-medial edge is attached to the medial surface of the pterygoid, as is all the muscle that lies on this bone. The remaining side of the triangle is that which lies along the lateral edge of the pterygoid. No part of this muscle could be seen going to the posterior part of the soft palate in the conventional way, as Miller describes for *Phoca*. It is difficult to relate the adequate functioning of the levator palati with the resistant, fibrous nature of the wall of the Eustachian tube, firmly applied to the medial surface of the pterygoid.

The tensor palati is a cylindrical muscle arising from the tympanic bulla ventro-lateral to the Eustachian tube, but not from it. It is otherwise as in *Phoca*, as described by Miller.

The palatoglossus is a thick band of muscle passing dorso-ventrally at the side of the tongue just anterior to the tympanohyal tube. Anteriorly the fibres spread out over the side of the tongue, merging with other tongue muscles. Posteriorly and dorsally the fibres go between the stylopharyngeus on the outer side and the pterygopharyngeus on the inner side, to the back of the pharynx. Miller says that this muscle in *Phoca* "arises by a few scanty fibres from the anterior surface of the soft palate, and blends with the styloglossus".

The palatopharyngeus forms the soft palate. It arises from the posterior edge of the hard palate. The more anterior, ventral fibres turn sharply so that they run transversely across the palate, and at the edges turn again to run longitudinally to the posterior end of the soft palate where they curve dorsally round the pharynx. The more dorsal fibres run longitudinally and curve laterally at their posterior ends. The great thickness of the muscular part of the soft palate has already been mentioned.

The stylopharyngeus is a stout muscle, crossed on its lateral surface by the external carotid artery

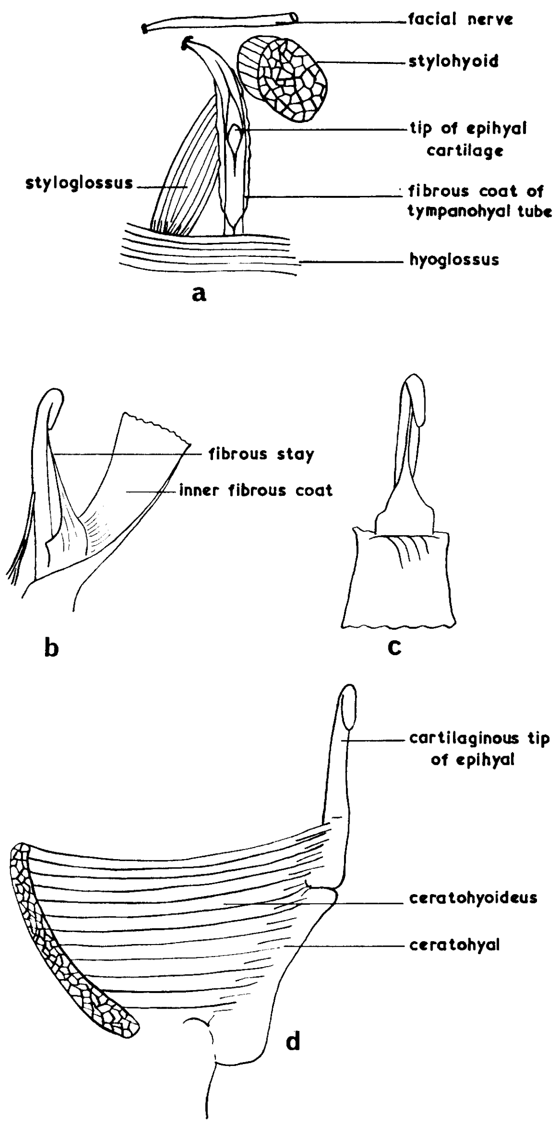


FIGURE 14

a. The right tympanohyal tube in position and split open to show the tip of the epihyal.
b. Posterior view of the tip of the right epihyal showing the inner fibrous coat of the tympanohyal tube opened out, and one of the inner fibrous stays.
c. Lateral view of the region shown in b.
d. Lateral view of the right anterior cornu of the hyoid to show the bent cartilaginous tip of the epihyal and the attachment of the ceratohyoid muscle.

(Fig. 11). It arises partly from the bulla posterior to the tympanohyal tube, and partly from the more dorsal and posterior parts of the fibrous wall of the tube. The muscle passes medial to the hyoglossus and goes to the dorsal surface of the pharynx, sandwiched between the inferior and middle constrictors.

The pterygopharyngeus has a circular insertion on the inner face of the expanded pterygoid just anterior to the pterygoid hamulus. The fibres pass medial to those of the palatoglossus and go round the back of the pharynx, emerging dorsal to the constrictors.

The pharyngeal constrictors are difficult to distinguish individually, and are very thick. Dorsal to the nasopharynx in the mid line the constrictor muscle is 3 cm. thick. The constrictors appear to conform to the usual pattern except that the middle muscle has a strong ventral band (Fig. 10). This lies immediately ventral to the junction of the anterior and posterior parts of the genioglossus; its mid-ventral part is covered by the geniohyoid, and its lateral parts by the hyoglossus. A small band of fibres branch off on either side and pass anteriorly to attach to the anterior end of the thyrohyal.

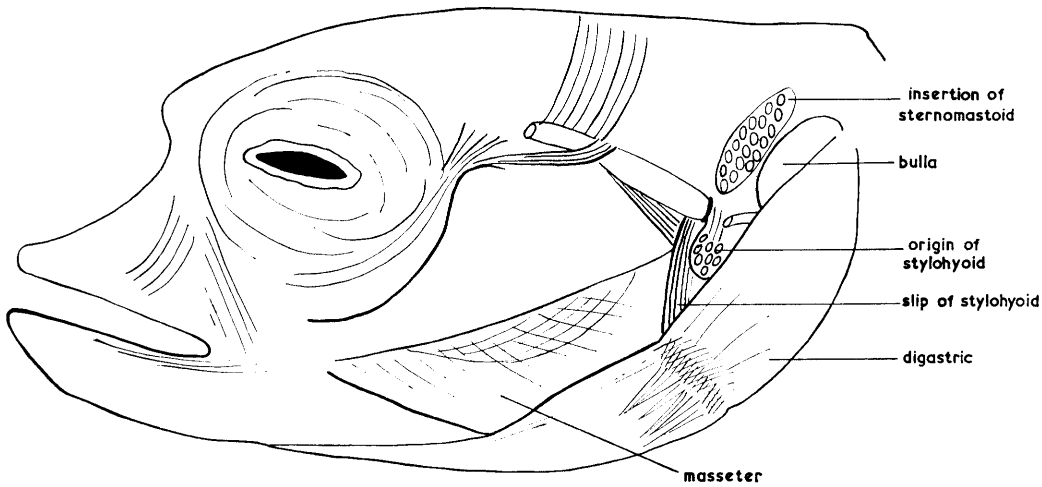


FIGURE 15

Left side of the head to show the masseter and digastric muscles

12. *Muscles of the lower jaw*

The masseter arises from the inner surface of the zygomatic arch from the squamosal-jugal junction, the whole of the ventral process of the jugal and the whole of the zygomatic process of the squamosal, and from the entire ventral edge of the jugal straight across on to the latero-caudal surface of the condyle of the lower jaw. The latter part is that called superficial by Howell, while the former seems to correspond with his deeper masseter. The muscle is inserted into the lateral surface of the coronoid process, the anterior face of the condyle and to what would normally be the more posterior part of the masseteric fossa. This fossa is almost unmarked as such in *Ommatophoca*, but the muscle is nevertheless large and strong, overlapping its insertion by a considerable extent, and lying as a rounded pad on the jaw.

Superficial and deep parts of the temporal muscle can be distinguished. The superficial temporal arises from the medial border of the temporal fossa and then merges with the deep temporal. The latter arises from the entire cranial surface of the rest of the temporal fossa, and both parts are inserted on the medial surface of the coronoid process. There is a strong tendon along the anterior edge of the muscle which is attached partly to the rising part of the coronoid, and partly above the angle of the jaw. There is some mingling of temporal and masseter fibres in the region of the zygomatic process of the squamosal. This is not unlike Howell's description of this muscle in *Zalophus*; in *Pusa* he says it is a very weak and less extensive muscle.

The temporal is separated from the orbit by the strong orbital sheath, but its anterior surface mirrors the posterior surface of the orbit. It is not attached to the postorbital process of the zygomatic, but touches it, and there is solid temporal muscle between this process and the cranium. The thickness and power of this muscle is not at all obvious from the skull with its lack of sagittal crest, but the width of the zygomatic arches allows great thickness of the muscle, which bulges like a cushion above the dorsal surface of the cranium.

The digastric (Fig. 15) is a strong, bulky muscle, almost circular in cross-section, with a well marked tendinous division about half-way along its length. Its origin is from the concave antero-lateral face of the projecting paroccipital process, and it then swells out and covers the posteriorly directed faces of the bulla, being inserted on the lateral face of the angle of the jaw and along the entire ventral edge of the jaw, lateral to the insertion of the mylohyoid, and almost to the symphysis. Its posterior insertion on the angle is entirely lateral, and not medial as in *Pusa*.

The internal pterygoid has a large origin on the lateral orbital surface of the palatine and pterygoid bones, extending to behind the glenoid cavity in the groove in the bulla postero-medial to the post-glenoid process. It is inserted into the subcondyloid process on the medial surface of the lower jaw. It is a large muscle, considerably overlapping its misleadingly small insertion.

The external pterygoid is a very small cylindrical muscle running from the inner side of the condyle of the lower jaw to its insertion just anterior to the foramen rotundum.

13. *Remaining head muscles*

The longus capitis is a large cylindrical muscle, only the cranial attachment of which could be investigated. This is in a hollow in the basioccipital and basisphenoid just medial to the bulla. The muscle has a strong tendon lying along its ventral surface, which at its anterior end is attached just medial to the anterior tip of the bulla and along about half of the ventral edge of the basisphenoid next to the bulla.

The rectus capitis anterior minor is a thin, strap-shaped muscle not easily distinguishable from the longus capitis, and attached just posterior to it on the basioccipital. Again, only the cranial end was noted.

14. *Discussion of the throat and jaw muscles*

The muscles of the hyoid, tongue, pharynx and jaw can be divided functionally into groups, although with overlap of function. These groups include the muscles for:

i. Opening the jaw and increasing the gape—digastric.
ii. Shutting and clenching the jaw—masseter, temporal, internal pterygoid.
iii. Gripping with the back of the tongue—styloglossus, hyoglossus.
iv. Gripping with the pharynx, and swallowing—stylohyoid, posterior parts of genioglossus, palatoglossus, palatopharyngeus, pterygopharyngeus, stylopharyngeus, pharyngeal constrictors.

In the description of these muscles it is noticeable how many times they are said to be large or bulky, and indeed the general impression of all the jaw and pharyngeal muscles is that they are well developed and powerful. Furthermore, there is also a diversity of their attachments, some of which are more extensive than those in *Phoca* indicating a greater power or a more complicated function. For example, the hyoglossus and genioglossus both have posterior attachments which are more diverse than in *Phoca*, and also the well developed thyrohyal tubercle* probably gives a stronger attachment to the hyoglossus than in *Phoca*. The internal pterygoid, with its origin nearly 2 cm. deep on the lateral surface of the palatine, and the extension of its origin to behind the glenoid cavity, probably also has greater power than in *Phoca*.

Some of the attachments are different from those in *Phoca*. The development of the paroccipital process, which is large in *Ommatophoca*, gives a posterior attachment for the digastric at a different angle from that in the less highly specialized seals where this process is not developed, and this probably results in a stronger pull. The strength of the muscle, and the lateral, very long attachment to the lower jaw, would give considerable positive power to the opening of the mouth, creating a wide gape. The palatoglossus passes round the back of the pharynx and is so disposed that it could help the gripping action of the other pharyngeal muscles. Such an arrangement is not found in *Phoca*.

The muscles seem to be particularly well developed for opening the jaw wide and then using the strength of masseters, temporals and internal pterygoids to get a very good grip on anything in the mouth, escape of the prey being made difficult by the very sharp, backwardly curved incisors and canines. A considerable bulk of a large prey could be contained in the large mouth cavity, being gripped at the back of the buccal cavity by the tongue and pharyngeal muscles. The method of attachment of the hyoid may perhaps be

* See p. 17.

explained by the need for a very expansible pharynx. The distance between the anterior edges of the ascending rami of the lower jaw could act as the limiting factor on the size of prey swallowed, and it is noteworthy, and perhaps significant, that this distance is very wide in the Ross seal, as is the whole skull in the region of the glenoid cavity. Unfortunately, it was not possible in the preserved heads to see how far the mouth would open, but in this respect it is interesting to note that Ray (1964) says of the Weddell seal: "The jaws can actually open almost 150 degrees and the sawing action on the ice is surprisingly effective." It is difficult to see from the skull alone how this very wide angle could be achieved, and it is not thought that the Ross seal can open its mouth quite as wide as this.

15. *Trachea*

The trachea (in the male animal) is 43 cm. long from the first tracheal bar to the bifurcation into bronchi. It is wide and flat; the external diameter at the first tracheal bar is 9 cm. and it then rapidly increases in width so that 12 cm. posteriorly it is 13 cm. wide; there is a subsequent gradual diminution in width so that at the point of bifurcation it is 7 cm. wide. The bronchi are very short and pass almost immediately into the substance of the lung.

The tracheal cartilages are only on the ventral surface of the trachea; the dorsal side, under the oesophagus, is of soft tissue only, with the trachealis muscle running between the dorsal tips of the bars. From the anterior end to the widest part of the trachea the bars change from being curved, convex ventrally, to being almost flat, and then continue in this form. Each bar is oval in transverse section and *c.* 5 mm. in antero-posterior length. The first tracheal bar is separated from the posterior end of the cricoid by a fibrous cushion; the dorsal tips of this bar are slightly divided (Fig. 16a and b) but the remaining bars are undivided.

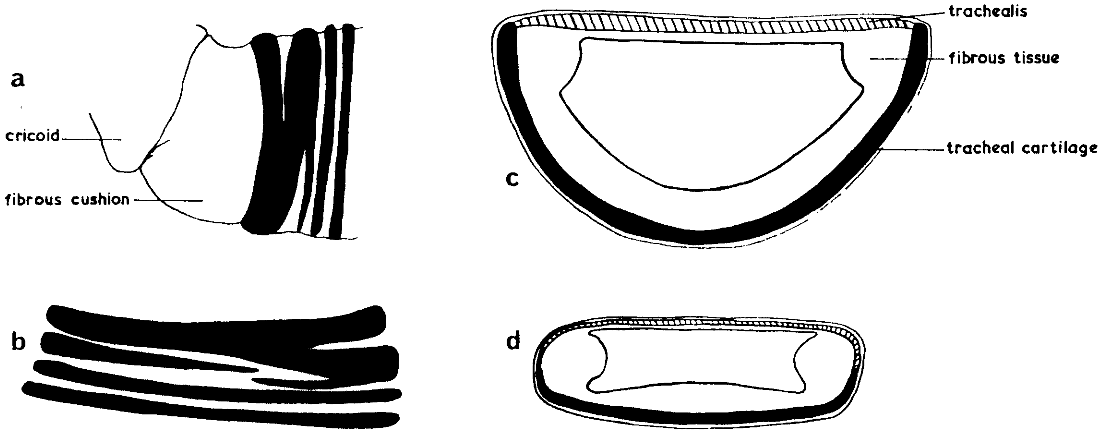


FIGURE 16

a. Lateral view of the anterior end of the trachea showing the first tracheal cartilages and the fibrous cushion.
b. Ventral view of the anterior tracheal bars.
c. Diagrammatic sections across the trachea immediately posterior to the larynx, and
d. Further back.

Internal to the cartilage is a layer of yellow collagenous-fibrous tissue, interspersed with fat cells. This tissue is very thin mid-dorsally under the trachealis muscle, but 6–8 mm. thick internal to the cartilage. It swells up laterally, internal to the dorsal tips of the tracheal bars to form longitudinal ridges (Fig. 16c and d) which extend along the entire length of trachea and bronchi. These would perhaps assist the soft dorsal roof of the trachea to spring back into its normal position after compression by bulky food passing down the oesophagus.

16. *Larynx*

Schneider (1962, 1963) is the only person in recent years to have investigated and compared the laryngeal structure in several pinnipeds. In most respects the larynx of the Ross seal agrees with the general characters for the phocid larynx as listed by Schneider (1962).

a. *Laryngeal skeleton* (Plate IXa, b, c). The two thyroid cartilages are separate, the pars interlaminaris being stiff but allowing easy movement of the two laminae. The latter were easily separable during dissection, there being 5 mm. between their innermost ventral ends. The thyroid tubercle is particularly well developed, and no thyroid foramen was found. The cricoid is long, hard, and almost cylindrical, its anterior dorsal edge being more prolonged than in *Phoca* and the other seals illustrated by Schneider. The arytenoid, triangular in cross-section, with a very well developed muscular process, does not seem to be peculiar in any way. The closeness of the first tracheal cartilage and the posterior end of the cricoid is mentioned by Schneider for the animals he describes; in *Halichoerus* for example, some of the tracheal cartilages have fused with the cricoid, and in *Mirounga angustirostris* the first tracheal cartilage is covered on the ventral side by the overlapping cricoid. In the Ross seal there is a considerable gap (*c.* 2 cm. mid-ventrally) between the cricoid and the first tracheal cartilage (Fig. 16a). This ventral part of the cricotracheal membrane, giving attachment to the cricothyroid muscle forms a thick fibrous pad, *c.* 1·4 cm. thick and appearing internally as a cushion, between the larynx and the trachea.

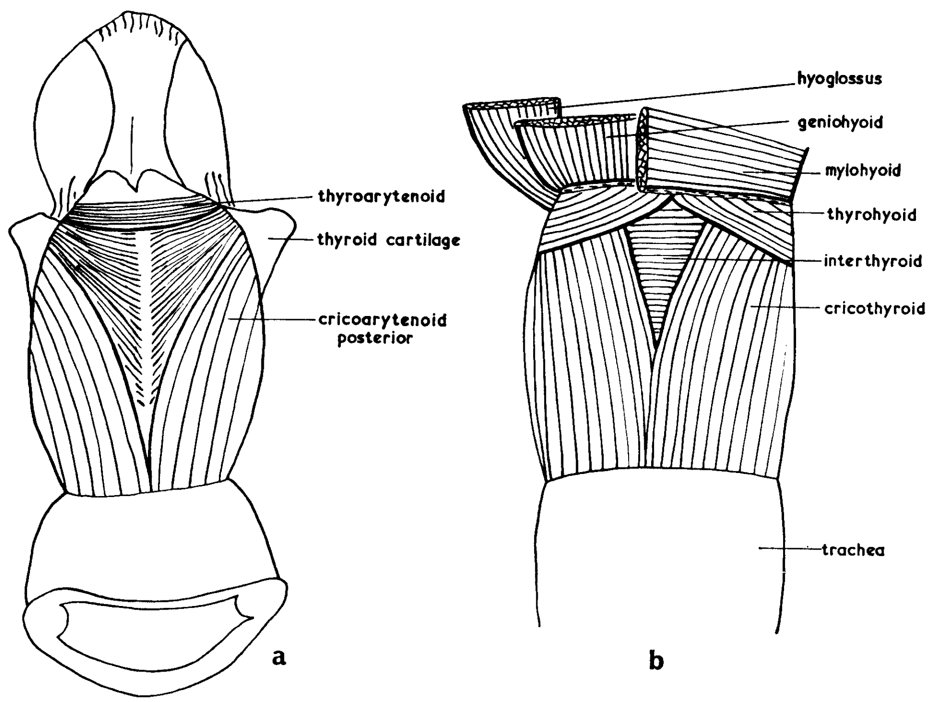


FIGURE 17
Superficial laryngeal muscles.
a. Dorsal view.
b. Ventral view.

b. *Laryngeal muscles.* The more superficial, longitudinal fibres of the cricothyroid (Fig. 17b) run from the cricotracheal membrane ventrally, pass dorsal to the thyrohyoid and attach to the antero-medial edge of the pronounced thyroid tubercle. The deeper, more oblique fibres run from the ventral surface of the cricoid to the posterior face of the thyroid tubercle and along the ventral rim of the thyroid cartilage. This is very similar to the arrangement of this muscle in *Phoca* as described by Schneider (1962), except that the demarcation of longitudinal and oblique fibres is less well marked in the latter seal.

The thyrohyoid runs from the posterior face of the ligament on which the mylohyoid ends, and from the posterior faces of the basihyal, thyrohyal, and thyrohyal tubercle* to the lateral face of the thyroid tubercle. It is also attached to the thyroid cartilage between these two tubercles.

The interthyroid (Fig. 18a and b) is a single muscle lying at right angles to the long axis of the larynx. It lies dorsal to both cricothyroid and thyrohyoid muscles and forms a dome-shaped mass, projecting ventrally and visible between the above muscles in the undissected larynx. It is attached to the inner

* See p. 17.

edges of the two thyroid tubercles and to a small part of the thyroid cartilages just anterior to the tubercles. It lies across the thyroid notch and is immediately ventral to the cricothyroid membrane. It is approximately 33 mm. in transverse length, 26 mm. antero-posterior length in the mid line, and 13 mm. thick. Its bulk gives the appearance of a powerful muscle; on contraction it would draw the thyroid tubercles closer together.

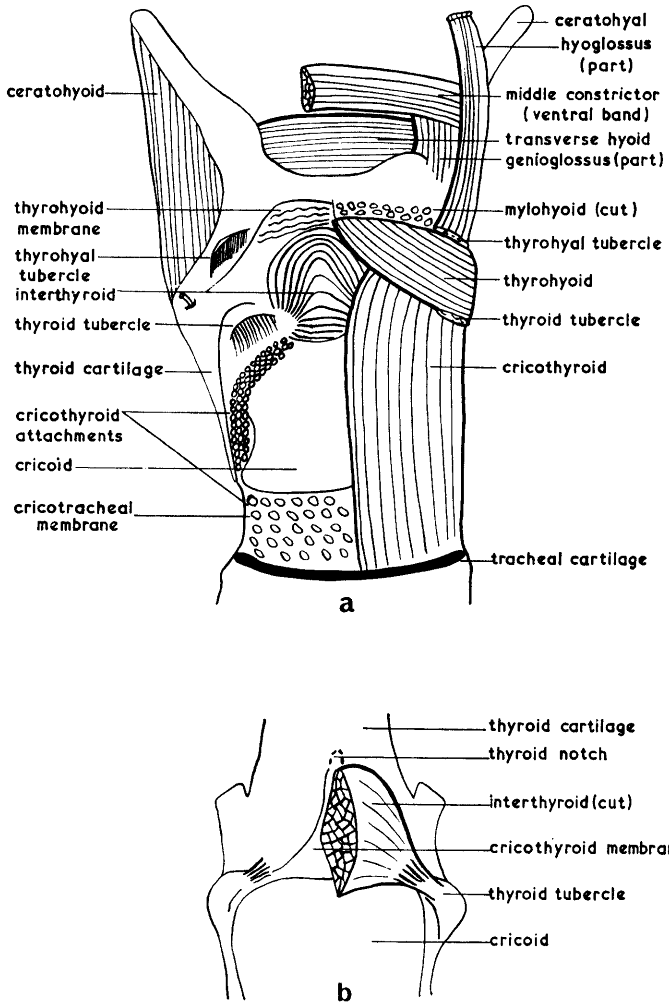


FIGURE 18

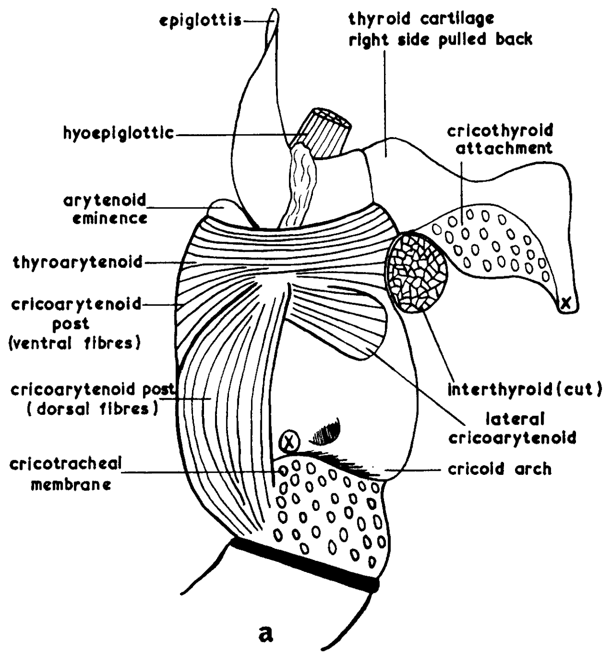
a. Ventral view of the hyoid and larynx with the thyrohyoid and cricothyroid muscles of one side removed.
b. Detail of the interthyroid muscle.

A muscle in this position is not noted by Schneider, and no mention of a similar muscle is found in the dog (Bradley, 1943), in the domestic animals (Sisson, 1930), or in man (Wood Jones, 1949). It is, therefore, here given the name interthyroid muscle.

The superficial fibres of the cricoarytenoid posterior (Fig. 17a), come from the posterior edge of the dorsal surface of the cricoid and go obliquely forwards to attach to the muscular process of the arytenoid. The deeper fibres come from a median raphe and proceed laterally, intermingling slightly with the superficial fibres. The more anterior of the deep fibres go past the muscular process and mingle with those of the thyroarytenoid. In some respects the cricoarytenoid posterior in the Ross seal is more like that illustrated and described by Schneider for *Zalophus* than for *Phoca* or *Mirounga*.

The lateral cricoarytenoid is as in *Phoca*. It runs from the antero-lateral angle of the ventral surface of the cricoid to the muscular process of the arytenoid.

The thyroarytenoid (Fig. 19a) is much as Schneider describes for *Phoca*, except that its posterior border merges with the cricoarytenoid posterior. From its ventral attachment on the inner side of the thyroid cartilage and from the cricothyroid membrane it continues in a circular manner across the dorsal mid line, so that an almost ring-shaped muscle is formed, enclosing the glottis. Schneider notes that in the Otariidae, and in *Pusa* and *Mirounga*, some of the superficial fibres of the thyroarytenoid merge into the interarytenoid so that a muscle arch is formed, although this is not obvious from his drawings. No separate interarytenoid muscle was noted in the Ross seal.



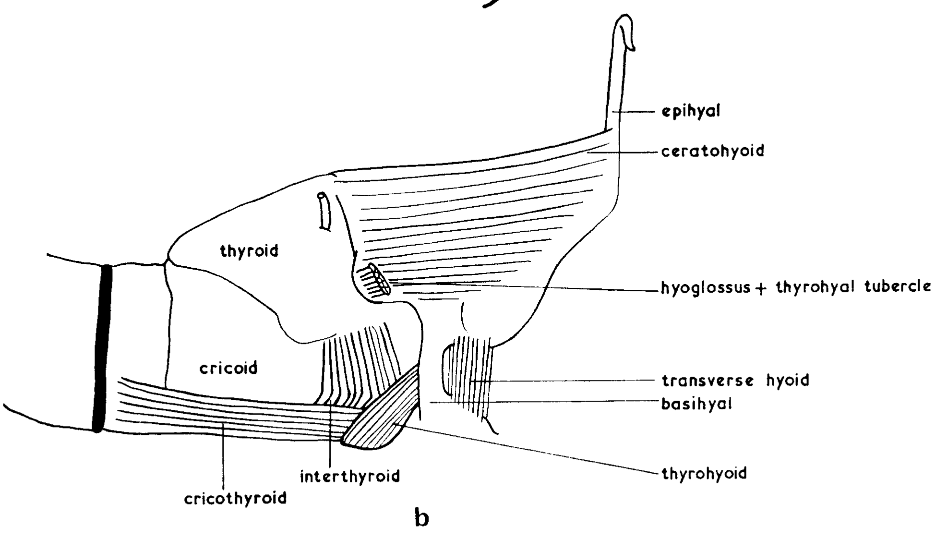


FIGURE 19

a. Lateral view of the right side of the larynx with the thyroid cartilage retracted.
b. Right side of the larynx and hyoid. Three-quarter view, showing lateral and part of ventral surface.

The hyoepiglotticus is attached to the anterior face of the epiglottis, but was cut before its presumed attachment to the hyoid was noted.

The often-repeated statement that the Ross seal has a distensible larynx seems to have been originated by Racovitza (1900) who notes "Son larynx fortement gonflé"; this is repeated by Brown (1915) ("The distended larynx acts as a resonator, and hence the explanation of the curious loud cry, which is quite characteristic and unmistakable") and more recently by Bonner and Laws (1964). Although there are some peculiarities of the larynx, there is no noticeable distension of any part, and in fact there are no laryngeal or vestibular sacs of any sort. Wilson (1907) says that "The prominence of the forehead and throat is as characteristic as it is peculiar, and results solely from the withdrawal of the head upon the neck".

H. Osteology

1. *Skull*

Until recent years, the number of Ross seal skulls available has been very limited, and little work has been done on them. Gray (1844) in his description of the type specimens gives, very briefly, some characters of the skull and teeth. Turner (1888) with the same two skulls is more concerned with noting the characters in which *Ommatophoca* and *Cystophora* agree. Barrett-Hamilton (1901) with the additional material of the *Belgica* expedition* restricts his remarks almost entirely to the variation in the teeth. This is the subject that again interests him in his report on the *Southern Cross*† collection (1902), and he agrees with Turner that there are resemblances to *Cystophora*. Wilson (1907), with an additional six skulls, also comments on the tooth variation and is interested in the apparent affinity with *Cystophora*. Thomson (1915) gives a detailed description of the two skulls brought home by the *Scotia*,‡ includes some comparison with skulls of *Leptonychotes* and *Hydrurga*, notes the dentition and also describes the skeleton. Pohle (1927) mentions only the dental variations. Turner (1912) and Scheffer (1958) give the main characters of the skull.

It has been possible to examine thirty-four skulls of *Ommatophoca*. Twenty-three of these are in the collections of the British Museum (Natural History), three have been borrowed from the Royal Scottish Museum, Edinburgh, two from the Institut Royal des Sciences Naturelles, Brussels, and one from the Zoologisches Museum, Berlin. Two skulls are in the Australian Museum, Sydney, one in the South Australian Museum, Adelaide, and two in the National Museum of Victoria, Melbourne. Their measurements are given in Appendix C.

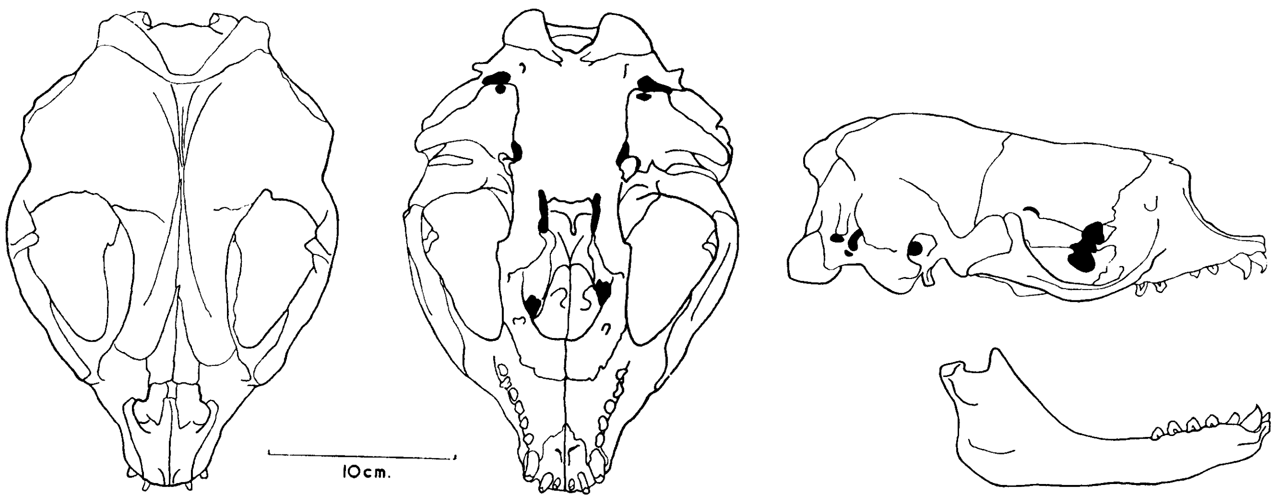


FIGURE 20
The skull of *Ommatophoca* 1949·2·3·1.
a. Dorsal view.
b. Ventral view.
c. Lateral view.

In proportion to the condylobasal length, and in comparison with similar proportions of other Phocids, the skull of *Ommatophoca* (Fig. 20) has a long cranium, long nasal bones and long orbits, is very wide at the external auditory meatus, and has a very short snout. The accommodation of the large eyes probably accounts for the very low position of the zygomatic arches, their ventral edges coming well below the level of the palate, and for the great width of the skull at the zygomatic arches. This latter width may also

* Belgian Antarctic Expedition, 1897–99, in the ship *Belgica*.
† British expedition, 1898–1900, in the ship *Southern Cross*.
‡ Scottish National Antarctic Expedition, 1902–04, in the *Scotia*.

be correlated with the width of the lower jaw at the coronoid processes and the swallowing of large prey (see discussion on jaw and throat muscles).

The persistence of the unossified anterior fontanelle (Fig. 21) has been noted before (Thomson, 1915).

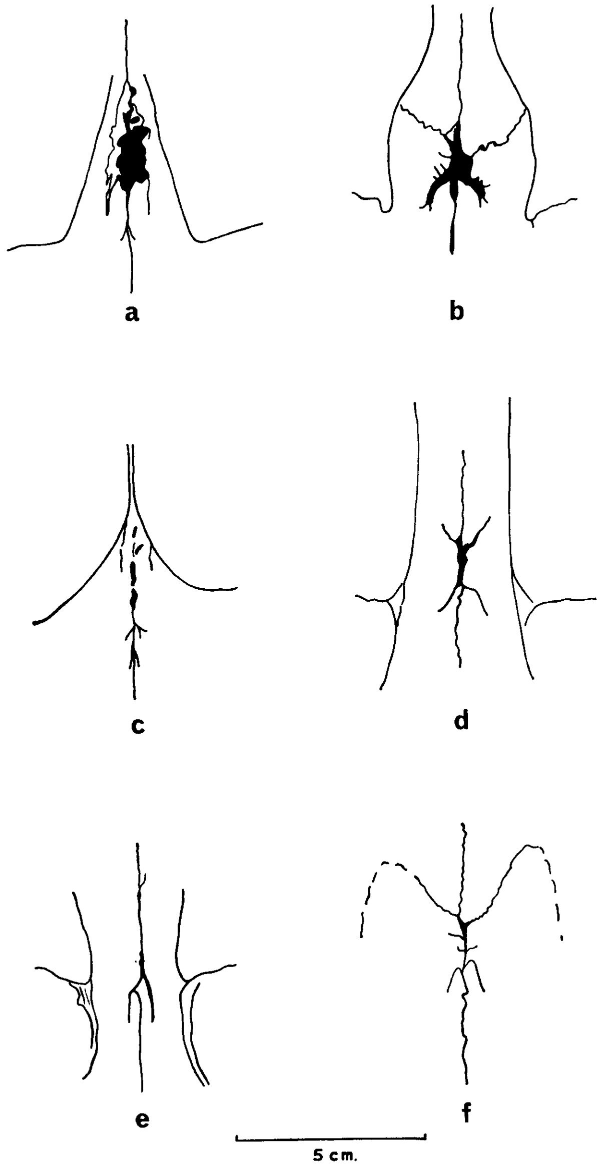


FIGURE 21

The anterior fontanelle, dorsal view.

Top row—widely open	a. 1908·2·20·47,
	b. Scotia No. 43.
Middle row—slightly open	c. 1951·4·24·1,
	d. 1901·1·4·13.
Bottom row—position visible	e. 1901·1·4·12.
	f. 1949·2·3·2.

It occurs in the mid line at the junction of frontal and parietal bones, is usually irregular in shape, and in one specimen (1961·2·24·2) the ventral layer of compact bone in this area fills the hole more completely than does the dorsal layer. There is no evidence that the size of the unossified area is correlated in any way with the age of the animal. The skull of the female seal that was dissected (1965·8·2·1) was broken in this area and the tissues damaged, but it seemed to be vascular tissue that was coming through the fontanelle. Some evidence of the fontanelle is visible in all thirty-four skulls, although the skulls from the frozen animals are too broken to assess its size. It is widely and unmistakably open in fourteen of them, the greatest dimensions of the biggest aperture being approximately 20×8 mm. (1908·2·20·47). It may be described as slightly, or very slightly open in eight skulls (e.g. 1951·4·24·1 and 1901·1·4·13), and closed but with the position visible in nine skulls (e.g. 1901·1·4·12 and 1949·2·3·2).

It is not exceptional to find a wide open fontanelle in a foetal skull, but it is rarely open for long after birth. Its persistence is remarkable in *Ommatophoca*, and it is interesting to note that three young and one sub-adult *Hydrurga* skulls show undoubted fontanelles. Lindsey (1937) records that "Infrequently a conspicuous parietal foramen (10×4 mm.) persists throughout the second month" in *Leptonychotes*.

Scheffer (1958, p. 9) says that "The [pinniped] skull is somewhat telescoped, the supraoccipitals overlapping the parietals." It is difficult to understand on what evidence this is based, but an overlap of varying degree of the frontal by the parietal occurs in most skulls. In all the Antarctic phocids (*Leptonychotes, Lobodon, Hydrurga* and *Ommatophoca*) the anterior part of the frontal overlaps the maxilla, and in a sub-adult *O. rossi* (1961·2·24·8) approximately 2 cm. of the posterior part of the maxilla is covered by the frontal (Fig. 22). Whether or not this overlap, caused by a well developed squamous suture, is "telescoping" is not discussed here.

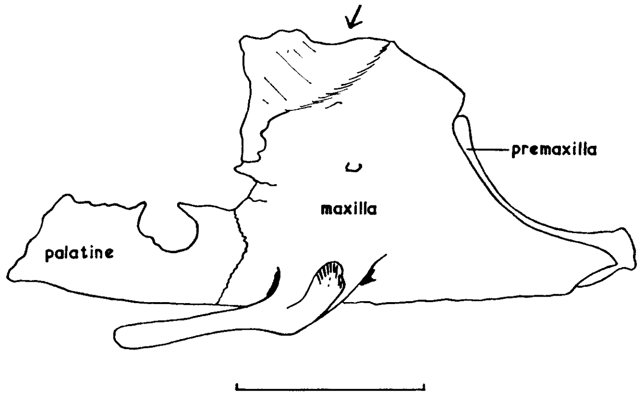


FIGURE 22

Ommatophoca, 1961·2·24·8. Left premaxilla, maxilla and palatine to show the part of the maxilla that is covered by the frontal (arrowed).

Another character possessed by *Ommatophoca* which is also common to the other Antarctic phocids is the tendency for the nasal bones to be completely fused into one unit. Of thirty-four *Ommatophoca* skulls, twenty-one have the nasals entirely fused, seven have a suture extending up to or less than half-way from the anterior end, two have a centimetre-long suture at the posterior end, and four have an entire suture so that there are two bones in the usual way. The fusion of this suture shows no correlation with age. The nasals vary greatly in size, ranging 47–80 mm. in length, and 19–32 mm. in width.

In young animals, where the fronto-parietal suture is clearly visible, there is a tendency in *Ommatophoca* for the mid-dorsal parts of the frontal, on each side of the mid line suture, to be prolonged posteriorly to a greater extent than in many seals (Fig. 23). Only in *Hydrurga* and *Mirounga* does there seem to be a comparable prolongation.

The anterior palatine foramina may be entirely surrounded by the premaxillae, or may have their posterior borders formed by the maxillae. The foramina are of variable, but usually moderate, size, with a transverse diameter of 3–4 mm., easily seen in a cleaned skull.

No differences between male and female skulls could be found, but there are not enough skulls of known females for a proper comparison to be made. No difference in the size of the canines was found.

The hard palate is short partly because of the shortness of the snout, but also because there is very little, if any, extension of the hard palate posteriorly, the posterior end of the inter-palatine suture being almost at the same level as the posterior edge of the maxillary branch of the zygomatic. The post-palatal area is of great depth, being bounded laterally by the dorsally extended orbital walls of the palatine and by the similarly enlarged pterygoids. The hamular processes of the pterygoids are very small. In many respects the hard palate and post-palatal area of *Hydrurga* are similar to these areas in *Ommatophoca*;

there is a short palate and deep post-palatal area with similar arrangements of palatine and pterygoid, and small hamular processes.

The triangular shape of the tympanic bulla is very similar to that of *Hydrurga*, in contrast with the more globular bulla of *Lobodon* and *Leptonychotes*. The thickness of the wall of the tympanic bulla is mentioned in the section on the ear. The lateral expansion of the squamosal dorsal to the external auditory meatus is composed of solid bone 3 cm. thick. This contributes to the wide spacing of the glenoid cavities, which is probably correlated with the swallowing of bulky prey.

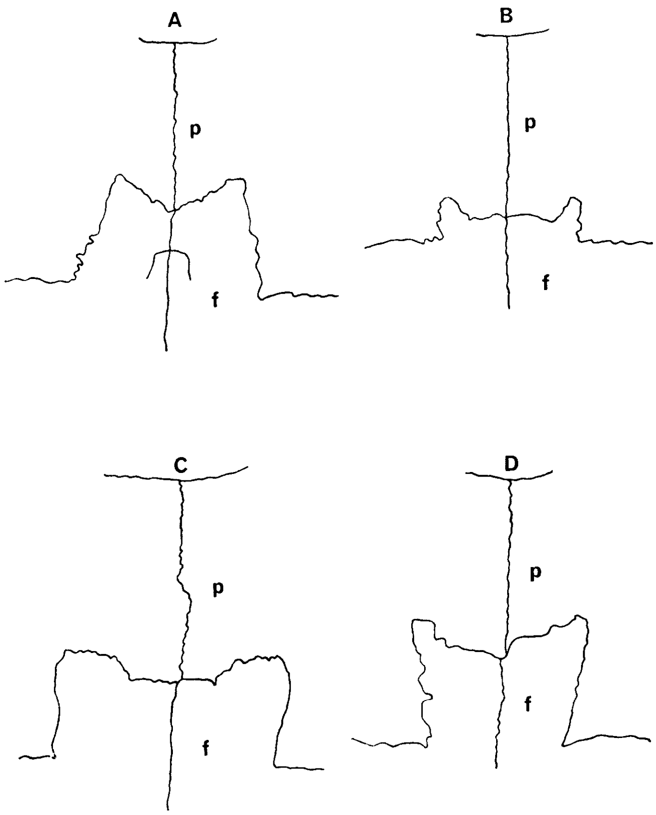


FIGURE 23

Fronto-parietal suture of
A. *Ommatophoca* 1908·2·20·49. B. *Leptonychotes* 1920·2·16·1.
C. *Mirounga* 1950·7·21·9. D. *Hydrurga* 1939·4·29·6.
p = parietal
f = frontal.

The cranial aspect of the petrosal cannot be described adequately without, at the same time, including descriptions of most other phocid petrosals for comparison. It has, however, the same basic anatomy, although the finer details of its shape, and more particularly its small size, are distinctive. All parts of it are small, the promontory housing the cochlea is hardly as big as that of *P. hispida*, and the entrance to the floccular or appendicular fossa is approached only by that of *Hydrurga* in relative inconspicuousness. This fossa would appear to be full of blood vessels, as they entirely filled the entrance.

The part of the cranial floor approximately bounded on each side by the sphenoidal fissure, foramen ovale, petrosal, and pituitary fossa, has what can most conveniently be described as a false floor. This is formed by a thin shelf-like lateral outgrowth of the basioccipital and basisphenoid on each side, which becomes fibrous and attached to the main lateral wall of the cranium immediately dorsal to the foramen ovale. The brain and the cranial nerves passing through the sphenoidal fissure lie dorsal to this shelf, and the internal carotid artery lies in a very deep bony groove in the normal floor of the cranium under the shelf. The space between the two layers of bone is about 4 mm. It has been suggested that this false floor may be ossification of the dura mater.

a. *Skull weight.* It is apparent when handling Ross seal skulls that for their moderate size they are very heavy. Table I compares the lightest and heaviest skulls with Weddell seal skulls of similar condylobasal lengths, and indicates the widely different weights of the latter. Lower jaws were not included.

TABLE I
WEIGHTS OF ROSS AND WEDDELL SEAL SKULLS OF COMPARABLE SIZE

	Length (mm.)	*Weight* (kg.)	*Length* (mm.)	*Weight* (kg.)
Ross seal	220	0·49	257	1·03
Weddell seal	222	0·29	259	0·45

A Leopard seal skull comparable in weight to that of the heaviest Ross seal skull has a condylobasal length of 354 mm., i.e. 97 mm. longer than the Ross seal skull.

Any comparable weights of different parts of skulls of various species are lacking, as they could only be obtained by causing considerable damage to the collection, and without them it cannot be said accurately which part or parts of the Ross seal skull are responsible for the heaviness. It is, however, most likely to be the tympanic region. The great lateral expansion of the squamosal part of the tympanic is of solid bone about 3 cm. thick, and the ventral, medial, and antero-medial walls of the bulla are about 12 mm. thick.

b. *Lower jaw and disease.* The symphysis is short and the anterior part of the jaw very narrow. The angle is rounded and thickened, and there is a well marked, roughened knob, the subcondyloid process, for the insertion of the internal pterygoid muscle. The coronoid process is short and pointed, rising only a little above the transversely elongated articular condyle. As has already been noted, the masseteric fossa is feebly marked, in spite of the size of the muscle.

In the skulls available there are no obvious signs of disease or abnormality except those connected with the glenoid cavity and the condyle of the jaw, and only one lower jaw shows signs of some damage to the horizontal ramus. The apparently "normal" condition of the condyle is a relatively smooth-surfaced parallel-sided articulating surface with its rounded face directed dorsally. There are departures from this "normal" state, consisting of varying degrees of roughening of the articular surface, and distortion so

TABLE II
THE FOUR YOUNGEST ROSS SEAL SPECIMENS

Nose–tail length	*Sex*	*Date caught*	*Locality*	*Notes*	*Reference*
4 ft. 3 in. (1·30 m.)	♂	16 December	64°22′S., 03°40′W. N.E. of Weddell Sea	—	*Norsel*
4 ft. 9 in.* (1·45 m.)	♂	12 December	60°26′S., 17°58′W. N.N.E. of Weddell Sea	Weight *c.* 90 lb. (40·8 kg.) Amphipods in stomach	Shackleton (1919)
5 ft. 6 in.* (1·68 m.)	♀	—	60°46′S., 44°40′W. Scotia Bay, Laurie I., South Orkney Is.	Estimated as 6 weeks old	Brown (1915)
5 ft. 11 in. (1·80 m.)	♂	January	69°S., 178°E. in pack ice, Ross Sea	—	Wilson (1907)

* Possibly not nose–tail length.

that the sides are not parallel (Fig. 24). Any gross change in the shape of the condyle is, of course, mirrored in the glenoid cavity. The most distorted condyle has practically none of the normal articular surface left; what little remains faces almost posteriorly, and the whole condylar area is flattened. The Berlin skull (36245) has a very obviously diseased condition of the condyles and glenoid cavities, where the bone is rough and pitted.

c. *The youngest skull.* The smallest Ross seal skull available (1961·2·24·6) is from a young male animal collected by the Norwegian-British-Swedish Antarctic Expedition personnel on board M.V. *Norsel*

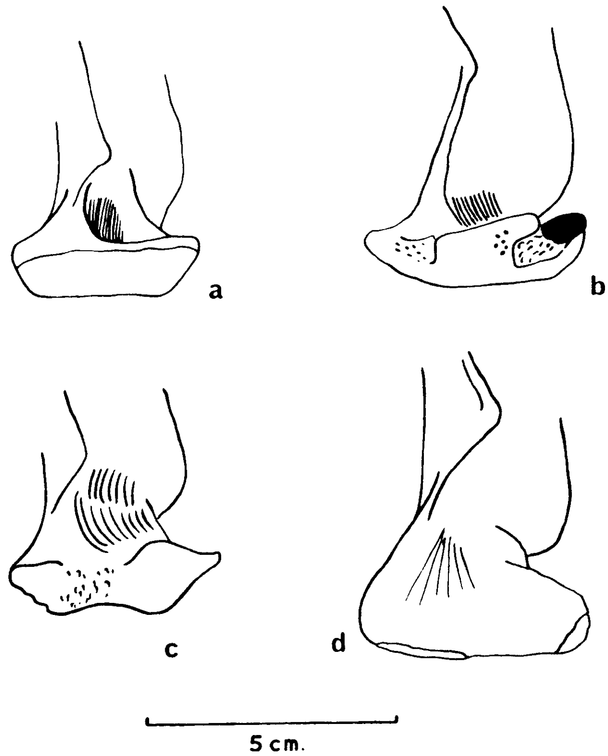


FIGURE 24

Normal and abnormal conditions of the right mandibular condyle of *Ommatophoca*.
a. 1961·2·24·3, normal.
b. 1908·2·20·48.
c. 1901·1·4·13.
d. 1961·2·24·2.

north-east of the Weddell Sea (lat. 64°22'S., long. 03°40'W.) on 16 December 1951. The nose–tail length of this seal was 1·3 m. (4·25 ft.). Although the skull was broken, its condylobasal length has been estimated to be 169 mm., and it is obviously from a very young animal.

Information on only one other animal of comparable size is known, and this has been given by Shackleton (1919). Two other larger, but still young, seals are noted by Brown (1915) and Wilson (1907). Information on these four very young Ross seals is summarized in Table II.

Although nothing is known directly about the breeding habits of the Ross seal, the information in Table II suggests that at birth the pups have a nose-tail length of about 1·2 m., and that the pupping time is in December and possibly also at the end of November. The birth weight is possibly about 27 kg., and this suggests that Shackleton's animal, with a weight of 40·8 kg., may have been about a week or more old and augmenting its milk diet with amphipods. The presence of young animals from both the Weddell Sea and the Ross Sea suggests that breeding takes place on the circumpolar pack ice. This estimated account of Ross seal breeding appears to correspond well with the general pattern indicated by what is known of the breeding habits of other Antarctic seals, summarized in Table III.

TABLE III

BREEDING HABITS OF FOUR ANTARCTIC SEALS

Seal	*Nose–tail length at birth*	*Weight at birth*	*Time of birth*	*Adult male nose–tail length*
Crabeater	4 ft. 6 in. (1·37 m.)	—	September–November	8 ft. 6 in. (2·59 m.)
Weddell	4 ft. 9 in. (1·45 m.)	60 lb. (27·2 kg.)	September–October	9 ft. (2·74 m.)
Leopard	5 ft. 2 in. (1·57 m.)	65 lb. (29·5 kg.)	November–December	10 ft. (3·05 m.)
Ross	4 ft. 3 in. (1·30 m.)	*c.* 60 lb. (27·2 kg.)	November–December	9 ft. 10 in. (3·00 m.)

2. *Teeth*

The variations, particularly in the roots of the teeth, have occupied most writers on this seal. Gray (1844–75), Barrett-Hamilton (1901, 1902) and Wilson (1907) go into considerable detail on the subject. Pohle (1927) is the latest contributor and he lists the variations in the number of teeth and the number of roots of all skulls (twenty) then available to him. His list has been used except for the *Scotia* skulls which, being accessible, were re-examined directly. The skull of *Southern Cross* No. 1 (1901·1·4·13) is listed by Pohle as having no postcanines, but re-examination proves that the alveoli are patent enough to be counted.

TABLE IV

VARIATION IN THE NUMBERS OF INCISORS AND POST-CANINE TEETH

Teeth		*Number of animals*	*Number of teeth*	
			Left	*Right*
Incisors	Upper	32	2	2
		1	3	2
		1	3	3
	Lower	33	2	2
		1	2	3
Post-canines	Upper	23	5	5
		6	6	6
		1	6	5*
		1	7	6
		1	5	4
		1	4	4
	Lower	26	5	5†
		3	6	6
		1	7	6
		1	4	5
		1	4	4
		1	6	4‡

* The first right post-canine of this specimen (1843·11·16·7, 324b) has a double crown but a single root, as illustrated by Gray (1844–75, pl. VIII, fig. 4).

† The first post-canine on both sides of the jaw of one specimen (1843·11·16·7, 324b) has a double crown and a single root similar to that in the upper jaw (see note above).

‡ The teeth of this specimen have been upset by damage to the right ramus.

In addition to the post-canines given in the table, male 1965·12·20·1 has 5–5, but the skull was broken and the teeth dislodged and although it is probable that this is the correct number it is not certain.

Using Pohle's table and augmenting it with the additional specimens now available, brings the total number of individuals for tooth counts to thirty-four. It is obvious that the normal dental formula is i$\frac{2}{2}$, c$\frac{1}{1}$, pc$\frac{5}{5}$, and the variation in number of incisors and postcanines is shown in Table IV. There is no variation in the number of canines.

By far the greater number of postcanines (except the first, which is always single-rooted) have double roots in the normal manner. However, the degree of bifurcation of the roots varies from those having the division merely indicated by a groove to those with the two roots widely separate. It is not considered that any useful purpose would be served by enumerating the conditions in individual teeth.

Barrett-Hamilton (1902) describes the teeth in great detail. He notes their feebleness and small size, and is particularly interested in the variation in number and in the degree of double-rootedness. With only eight skulls at his disposal the variation must have seemed excessive, but with the greater number of skulls now available the variation is seen to be less remarkable, though perhaps still greater than one would expect. To summarize the variation, if each skull is taken as having 4 sides (i.e. 2 upper and 2 lower), 6 of the sides have 4 postcanines, 101 have 5, 22 have 6 and 2 have 7. Similarly, for the incisors, 132 sides each have 2 incisors, and 4 have 3 incisors.

Only the co-type 324b is peculiar in having three postcanines each with a double crown and single root, although the *Southern Cross* No. 2 (Oslo 7523) is said to have a lower postcanine with the crown deeply divided by a groove.

3. *Skeleton*

Thomson (1915) compared the specimen collected by the *Scotia* with the incomplete type skeleton. The following description of the two new skeletons includes a limited comparison with the type specimen, the Sydney skeleton from the Australian expedition, and other southern phocids.

a. *Vertebral formula:*

1965·8·2·1	♀	C7	Th15	L5	S3	Cd11
1965·12·20·1	♂	C7	Th15	L5	S2	Cd13
Type—324a		C7	Th14	L5	S3	Cd—
S1360	♂	C7	Th15	L5	S2	Cd12

The vertebral epiphyses are fully fused, up to and including the sacrum, in all four specimens. Epiphyses are visible at the posterior end of the fifth caudal vertebra and at both ends of the subsequent vertebrae of 1965·8·2·1; a similar arrangement starts at the sixth caudal vertebra of 1965·12·20·1.

b. *Cervical vertebrae.* The atlas is of conventional shape, with stout lateral processes. Thomson (1915) notes that the odontoid process of the axis is small in the *Scotia* animal, but gives no measurement. Measured from the tip to the posterior end of the articular surface, the process is 18 mm. long in the type, 22 mm. long in S 1360 and 24 mm. long in 1965·12·20·1. Bullet damage prevents measurement in 1965·8·2·1.

The neural spine of the axis shows variation in shape. In the type it is high and extends almost at right angles to the centrum with practically no overhang anteriorly. The dorsal part is deep dorso-ventrally, approximates in bulk to the dimensions of the centrum, and has paired processes projecting posteriorly (Fig. 25a). Specimen 1965·12·20·1 has the neural spine projecting slightly anteriorly, a single dorsal ridge and a single posterior process (Fig. 25b); 1965·8·2·1 is similar but with the dorsal ridge thickened and roughened. In S1360 the two sides of the neural arch do not meet dorsally and the bone is pitted and abnormal. The transverse process of the axis is a small, single, backwardly pointing spine in the type and 1965·12·20·1, but is terminally bifid in 1965·8·2·1. The dorsal root of the transverse process, over the vertebrarterial foramen is extremely thin.

Thomson (1915) notes the short wide nature of the centra of the cervical vertebrae, and illustrates this by an index which is incorporated in Table V.

Thomson compares the index for the *Scotia* Ross seal with that of a leopard seal (92·16) and a Weddell seal (100).

The centra of cervical vertebrae 2–5 have a wide thick keel on the ventral surface, expanding almost to a knob on the posterior face (Fig. 25c). This is abruptly replaced in vertebrae 6 and 7 by a thin ridge. Transverse processes are widest and slimmest in C3 and get progressively shorter and thicker towards C7. The lateral tips of the transverse processes are divided, to a greater or lesser degree, into dorsal and

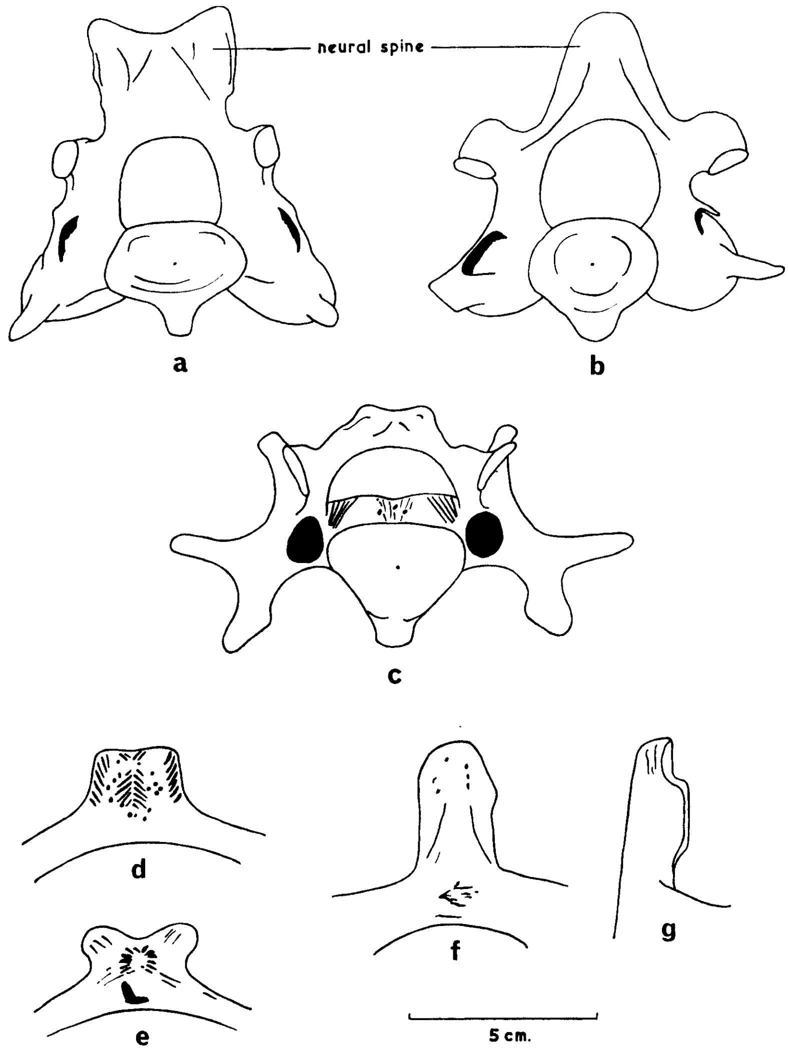


FIGURE 25

a., b. Posterior view of the axis of 324a, and 1965·12·20·1, respectively, to show the difference in shape of the neural spine.
c. Posterior view of C4 of 1965·8·2·1.
d., e. Posterior view of the neural spine of C6 of 1965·8·2·1 and 1965·12·20·1 to show variation in shape.
f., g. Posterior and lateral views of the neural spine of C7 of 324a, to show the concave posterior face.

TABLE V

MEASUREMENTS OF CENTRA OF 5TH CERVICAL VERTEBRAE

	Specimen				
	1965·8·2·1 (female)	*1965·12·20·1* (male)	*Type 324a*	*Scotia* (male)	*Aurora S1360* (male)
Length (mm.)*	30	30	32	33	31
Breadth (mm.)*	42	41	41	48	35
Index†	140·0	136·6	128·1	145·4	112·9

* Measurements taken on the fifth cervical vertebra. Thomson (1915) says fourth but he meant the fourth of the posterior six vertebrae.

† $\frac{\text{Breadth} \times 100.}{\text{length}}$

ventral processes as is usual. However, this is hardly more than a bifurcation in the anterior vertebrae (Fig. 25c), the ventral branch not forming the usual expanded plate, and the transverse process being very like that of *Monachus tropicalis*. C7 of 1965·8·2·1 has the normal undivided transverse process on each side and, in addition, on the left side there is a stout ventrally directed process springing from the junction of transverse process and centrum.

The neural arch is narrow. The neural spine is hardly perceptible on C3, and increases in height towards C7. It has a variable tendency to be bifid, and on C5, 6 and 7 is flattened or even concave on its posterior surface (Fig. 25d, e, f, g). Although the overall shape of the cervical vertebrae is similar in the three animals, the details show considerable variation.

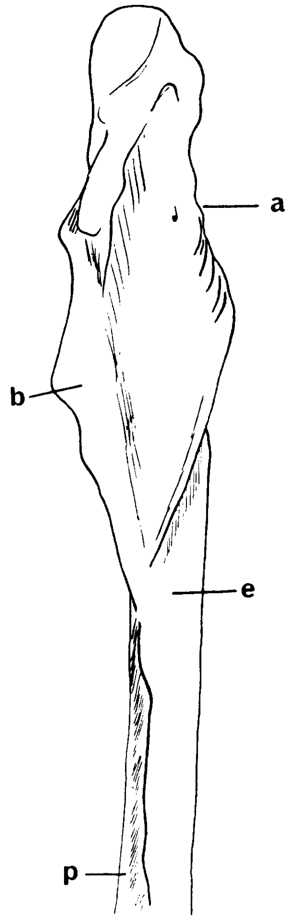


FIGURE 26

Rib R13 of 1965·8·2·1.

a. Ridge on antero-internal angle.
b. External ridge.
e. External face of rib.
p. Posterior face of rib.

c. *Thoracic vertebrae*. The rest of the vertebral column shows fewer characters of note than the cervical vertebrae. There is a pronounced, thick keel on Th 1–5 diminishing posteriorly. This is similar in the type and the *Scotia* seal, but in these is on Th 1–4 only. The neural spines are slender, diminishing in height from Th 2–7, and thereafter low and rounded.

The vertebrae of the female, 1965·8·2·1, are conspicuously larger than those of the male 1965·12·20·1. The following measurements (Table VI) are taken on Th 9.

This suggests that the type specimen might be from a female, and the innominate bones also indicate this.

d. *Lumbar*, *sacral and caudal vertebrae*. The rounded neural spines of the thoracic vertebrae are

TABLE VI

DIMENSIONS OF 9TH THORACIC VERTEBRA (mm.)

	Specimen			
	1965·8·2·1 (female)	*1965·12·20·1* (male)	*S1360* (male)	*Type 324a*
Centrum length	43	39	40	44
Maximum width between transverse processes	120	92	98	106

continued into the lumbar series. There is a variable degree of fusion of an additional (third) vertebra to the sacrum: it has not begun in the male, and is incomplete in the female and complete in the type. The articular surface for the ilium is on the first sacral vertebra only. The tail is complete in both male and female. In female 1965·8·2·1, there are eleven vertebrae, the first two of which have a small neural arch; in male 1965·12·20·1, there are 13 vertebrae with a neural arch on the first three.

e. *Ribs.* In both 1965·12·20·1 and 1965·8·2·1 there are fifteen ribs on each side. In the former the two proximal articular surfaces are distinguishable up to and including rib 11, and in the latter, rib 12. In female 1965·8·2·1, the internal face of the dorsal third of the rib is rounded in the normal way up to and including rib 4, but thereafter there is progressive widening of this part of the rib, so that from ribs 7–13, inclusive, the upper part of the rib presents a wide flat surface on its inner side. This is quite different from the leopard and grey seals, for example, in which the rounded surface is kept throughout the series. This flattening is not so obvious on the ribs of the male, but can be seen on ribs 10–13. It may become more obvious with increasing age.

The ribs of the Ross seal, particularly those of the larger (female) animal, give the appearance of providing attachment for well developed muscles, as bony ridges are well in evidence. On the antero-internal angle, a sharp ridge (Fig. 26a) is evident from rib 4 to the posterior end of the series. This ridge is present, but not so obvious, in leopard and grey seals. The external ridge (Fig. 26b), continuing the line of the tuberculum is deflected backwards and overhangs the posterior face of the rib shaft, making the latter concave. These ridges have developed to such an extent that orientation of the last two ribs of the series is difficult.

f. *Sternum.* The sternum of both the male and the female seal is composed of eight sternebrae. In the male the presternum is laterally compressed, but the flattening becomes increasingly dorso-ventral on successive sternebrae. The xiphisternum is elongated, rounded in section, and is prolonged by a rod of cartilage with a semicircular expansion at its posterior end. Nine pairs of sternal ribs are attached, the first to the anterior end of the presternum. Between the xiphisternum and its anterior neighbour two pairs of sternal ribs are attached and there is evidence of an irregular nodule of ossification. Anterior to the presternum is an elongated rod of cartilage in which there are signs of ossification (Fig. 27a).

The sternebrae of the female are larger and flatter, but apart from the xiphisternum the arrangement is the same as in the male. The xiphisternum is dorso-ventrally flattened, and its posterior end is bifurcated and prolonged into two cartilaginous rods which in the prepared specimen are incomplete (Fig. 27b).

Seven of the disarticulated sternebrae of the type specimen are available. The presternum shows the place of attachment of the ribs at its anterior end and the cartilaginous extension with ossified nodules in it. The posterior end of the xiphisternum is circular in cross-section, and there is a large irregular ossified nodule attached to its anterior end.

g. *Baculum.* The baculum is 172·5 mm. long, flattened on its dorsal surface and rounded ventrally. The proximal end is slightly swollen ventrally and the distal end is deeply divided in the mid line (Fig. 36). That of the *Aurora* skeleton is 146 mm. long, and the distal end is not deeply divided.

h. *Scapula.* The scapula of the female has an undulating medial surface, whereas that of the male is almost flat except for a shallow concavity anteriorly. The anterior margin of the male scapula forms a more acute (rounded) angle with the coracoid than in the female. The anterior profile of the blade is thus longer and less convex in the male than in the female. The acromion process of the male is hardly more than a small triangular elevation of the low spine, that of the female is larger and knob-like in shape

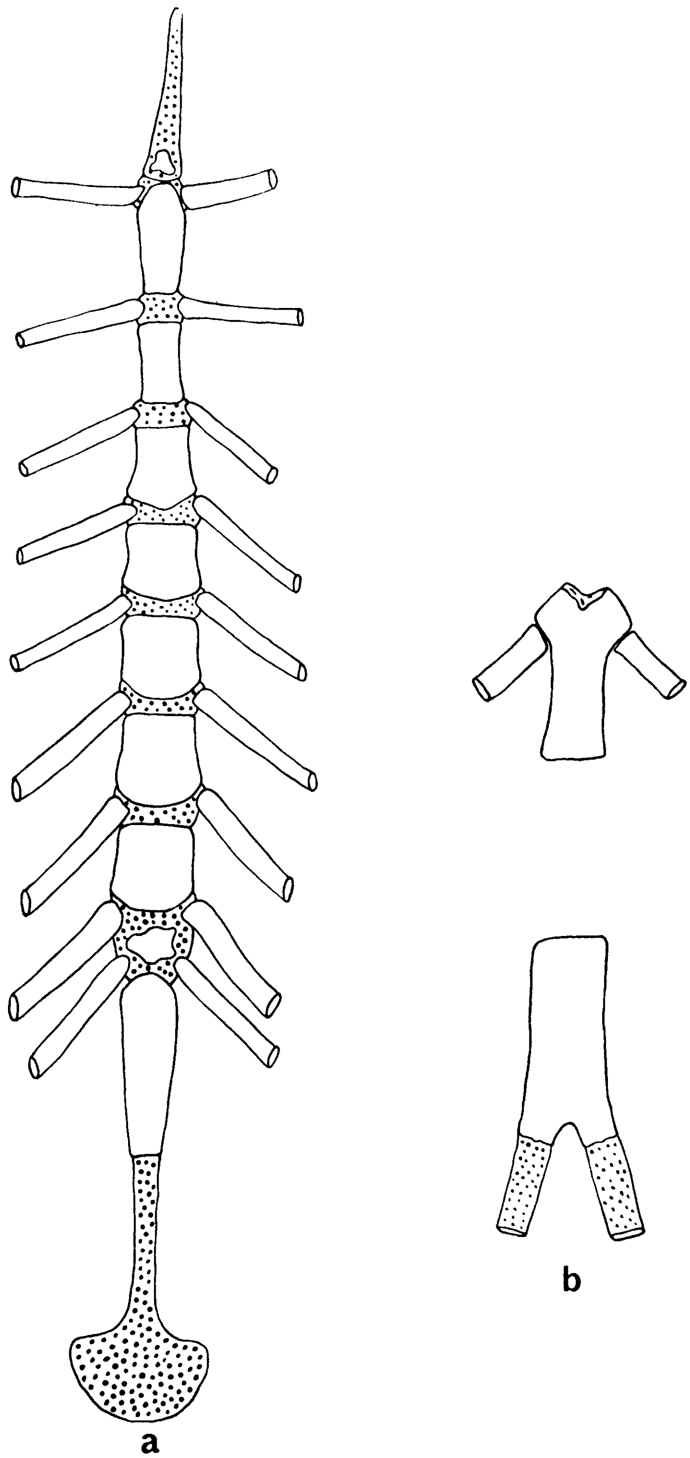


FIGURE 27

a. Ventral view of the sternum of 1965·12·20·1.
b. Presternum and xiphisternum of 1965·8·2·1 (cartilage spotted).

(Fig. 28). The glenoid cavity is roughly pyriform in outline. The foregoing differences between the two specimens available are such that no comparison has been made with other genera.

i. *Humerus*. The humerus is short and stout (Fig. 29a) with a great development of the antero-medially flattened lateral tuberosity. It is different in this respect from the entirely anteriorly directed projection of the tuberosity and deltoid crest of *Hydrurga* and *Leptonychotes*.

The posterior view of the distal end of the humerus of the female seal shows that the articular area is in two distinct facets (Fig. 29b) which articulate with a corresponding pair of facets on the ulna (Fig. 32a). In the male, while it is clear that there are similar points of contact between humerus and ulna, there is no distinct separation between the facets (Fig. 29c). The humerus of the *Aurora* skeleton (male) also has a single facet. A single oval facet on the humerus of *Hydrurga* articulates with a similar single facet on the ulna.

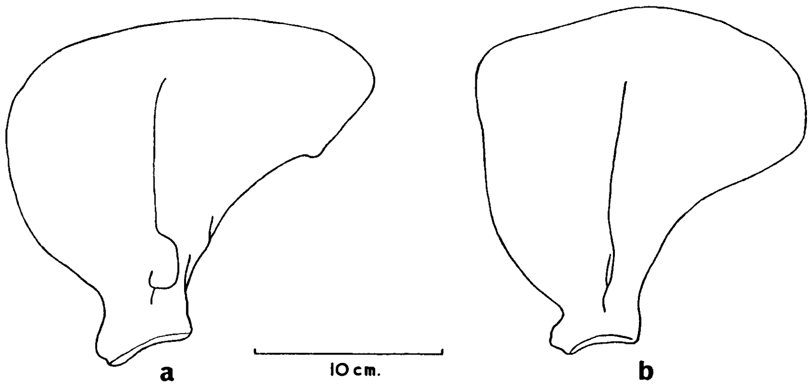


FIGURE 28

Scapulae of male and female *Ommatophoca*.
a. Female, 1965·8·2·1.
b. Male, 1965·12·20·1.

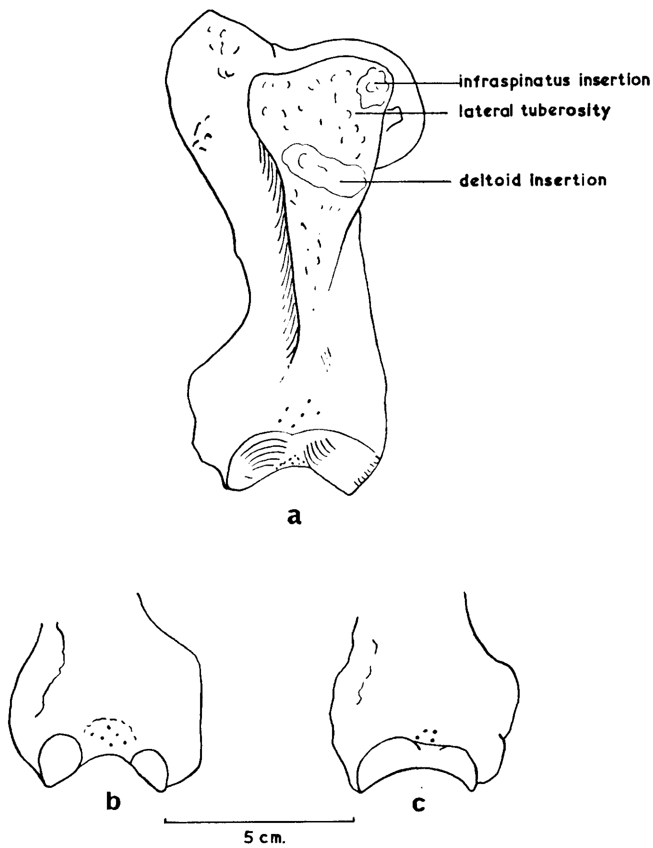


FIGURE 29

a. Anterior view of left humerus of 1965·8·2·1. The scars of insertion of the infraspinatus and deltoid muscles are indicated.
b. Posterior view of the distal end of the left humerus of 1965·8·2·1.
c. Similar view of 1965·12·20·1.

The length from head to tip of the lateral condyle in female 1965·8·2·1 is 116 mm., in male 1965·12·20·1 117 mm., and in *Aurora* male S1360 124 mm.

j. *Radius* (Fig. 30). The proximal articular surface is oval in outline, with the shorter diameter pre-postaxial; in *Hydrurga* it is circular.

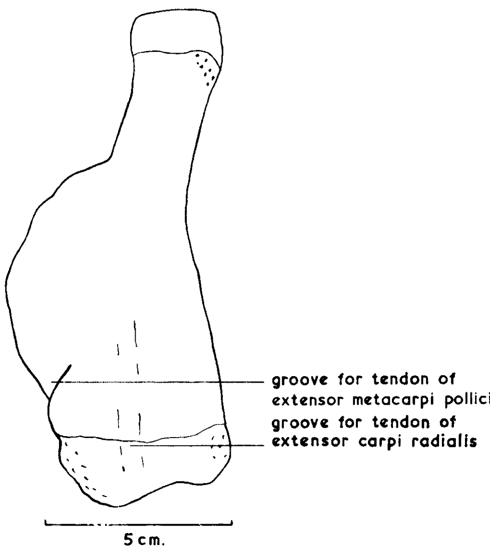


FIGURE 30
Lateral view of the left radius of 1965·12·20·1.

In both *Ommatophoca* and *Hydrurga*, the distal articular surface is concave towards the postaxial side and convex towards the preaxial side (Fig. 31). In *Hydrurga* the concave area forms the greater part of the surface, and the convex area extends from the preaxial-medial corner of it and curves on to the medial (flexor) side of the bone. In *Ommatophoca* the two parts are more nearly equal in area and extend in an almost straight line across the distal end of the radius. The convex area is flatter than in *Hydrurga*, but also curves on to the flexor side. The whole of these two parts of the surface articulates with the complementary one on the scapholunar, which is thus different in shape in the two genera.

The length of the radius, in straight line along the postaxial side in female 1965·8·2·1 is 128 mm., in male 1965·12·20·1 121 mm., and in male S1360 116 mm.

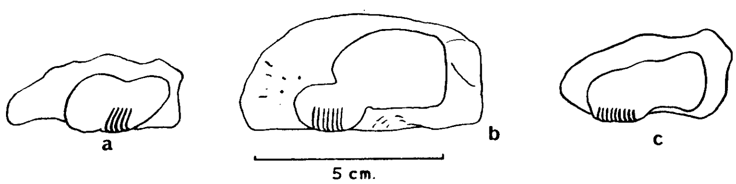


FIGURE 31
The articular area of the distal end of the radius. a. *Halichoerus*, b. *Hydrurga*, c. *Ommatophoca*. The postaxial side of the bone is on the right. The extension of the articular on to the flexor side of the radius is hatched. This extension is saddle-shaped (concave in the pre-postaxial direction, convex in the medial-lateral direction) in *Halichoerus*, but is convex in both directions in *Hydrurga* and *Ommatophoca*.

k. *Ulna*. In the female the articulations within the semilunar notch (Fig. 32a) are the two proximal facets which articulate with the humerus as noted above, and a distal one. The latter is composed of two surfaces, which are continuous but at right angles to one another. The larger, anteriorly directed facet articulates with a postaxial facet on the radius, and the smaller, proximally directed one with the humerus. Although the articular areas of the ulnae of the male seals (Fig. 32b) are of the same general shape as that of the female, all the articular surfaces are continuous. The lower end of the ulna of all three animals has an almost horizontal, oval facet for articulation with the cuneiform, in this respect being more like that of *Hydrurga* than the more rounded facet in this position in *Leptonychotes*.

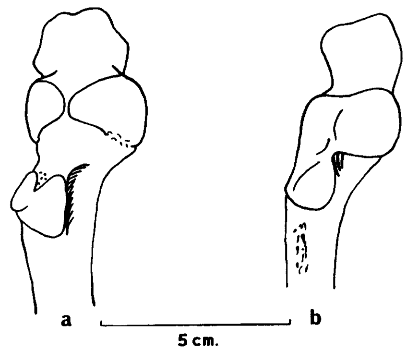


FIGURE 32
Anterior view of the semilunar notch of the left ulna.
a. 1965·8·2·1.
b. 1965·12·20·1.

The greatest length of the ulna in female 1965·8·2·1 is 157 mm., in male 1965·12·20·1 149 mm., and in male S1360 150 mm.

The differences between the male and female scapulae, humeri and ulnae can only be put on record at this stage. More specimens are needed before these can be interpreted in terms of age, sex or individual variation.

l. *Carpus. Ommatophoca* and *Hydrurga* have similar sets of carpal bones, and in almost all instances they articulate with similar neighbours (Fig. 33), but the shapes of the articular surfaces are frequently different. The following list shows the articulations of the various surfaces of the carpal bones of the Ross seal and the differences, where they occur, in the leopard seal. Articulating pairs of surfaces were given the same letter. (mc = metacarpal.)

Ross seal

A. radius — scapholunar
B. radius — cuneiform
C. ulna — cuneiform
D. ulna — pisiform
E. pisiform — cuneiform
F. cuneiform — unciform
G. cuneiform — lateral part 5th mc
H. unciform — scapholunar
I. unciform — magnum
J. unciform — medial part 5th mc
K. unciform — lateral part 4th mc
L. magnum — scapholunar
M. magnum — trapezoid
N. magnum — medial part 4th mc
O. magnum — 3rd mc
P. magnum — medial part 2nd mc
Q. trapezoid — scapholunar
R. trapezoid — trapezium
S. trapezoid — middle part 2nd mc
T. trapezium — scapholunar
U. trapezium — lateral part 2nd mc
V. trapezium — 1st mc

Leopard seal

J. is a very long surface. The articulation of the lateral (plantar) part is unciform—medial part 5th mc. The articulation of the medial (palmar) part is unciform—palmar part 4th mc.
K. unciform—plantar part 4th mc.
N. an extremely small surface on the magnum, not obviously touching any bone adjacent.

More comparative work than is relevant to this paper is required for an adequate assessment of the significance of these differences.

The potential movements of the carpus are difficult to estimate from the bones alone, but there is, for example, a considerable difference of radius—scapholunar articulation in *Halichoerus*, *Hydrurga* and *Ommatophoca* (Fig. 31), which points to differences in the movement of the flipper.

A rocking movement of the scapholunar on the radius in *Halichoerus* permits the considerable movements of flexion and hyperextension that can be achieved. It is the extension of the distal articular surface of the radius on to its flexor side that allows the flexor displacement of the scapholunar.

In *Hydrurga* this extension of the articular surface is shifted towards the preaxial edge of the radius

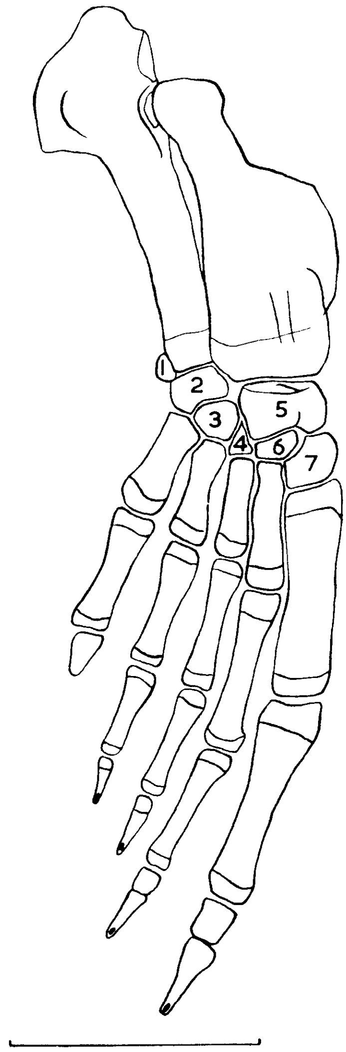


FIGURE 33

Lateral view of the right fore flipper of 1965·12·20·1.
1. Pisiform, 2. Cuneiform, 3. Unciform, 4. Magnum, 5. Scapholunar,
6. Trapezoid, 7. Trapezium.

and is convex. This allows a twisting movement of the scapholunar but it is almost impossible to produce a rocking movement.

The distal articulation of the radius of *Ommatophoca* is very much as in *Hydrurga* except that the convex part is less towards the flexor surface and more towards the preaxial edge. A smooth twisting movement is again possible and is appropriate to the delicate adjustment needed when the whole flipper is used in a hydroplaning action.

m. *Manus.* The radiograph of the Ross seal manus (Plate Xa) and inspection of the bones themselves reveal a number of interesting features. The elongated, strong metacarpal of the first digit and the very small intermediate phalanx of the fifth digit are characteristic of the southern phocids. Leboucq (1904*a*) noticed this reduction in foetuses of *Lobodon* and *Leptonychotes*, but does not appear to have looked at bones of adult animals. The shapes of the metacarpo-phalangeal and interphalangeal articulations are those typical of the Monachinae (King, 1966).

One of the most curious features of the manus, and one that was not at first easily interpretable on the radiograph, is the presence of very elongated epiphyses on the terminal phalanges (Table VII and King, 1965). So big are these, particularly that on the first digit, that they were at first thought to be

TABLE VII

DIMENSIONS OF TERMINAL PHALANGES OF MANUS (mm.)

Specimen	*1965·8·2·1* (female)					*1965·12·20·1* (male)				
Digit	1	2	3	4	5	1	2	3	4	5
Length of terminal phalanx including epiphysis	55	36	28	25	20	41	31	25	20	—
Length of epiphysis	24	13	8	7	9	18	9	6	4	—

extra phalangeal bones. There is, however, a smooth articulating surface on the proximal face of the epiphysis and a normal cartilaginous epiphyseal junction with the phalanx shaft at the distal end. Other epiphyses on the manus are of "normal" dimensions. Inspection of the phalanges of other phocids and radiographs of the bones left in prepared skins show that, except for *Hydrurga*, no other phocid has these enlarged epiphyses on the fore flipper, nor have they been seen in the Otariidae. Even those of *Hydrurga*, while clearly of the same sort, are not quite so big. All available fore flippers of *Ommatophoca* show them. Because terminal phalanges of seals are frequently left in prepared skins, complete flippers are not very abundant. From the available material, however, it appears that the epiphyses of the terminal phalanx of the first digit is one of the early ones to fuse with its shaft, but in the Ross and leopard seals it seems that fusion is delayed.

It was noted earlier that the soft tissue of the first digit extends beyond the nail for 3·8 cm. If the tip of the digit is carefully dissected it can be seen that this extension is supported by a lanceolate piece of cartilage which surrounds the terminal 5–6 mm. of the bone, and extends 23 mm. beyond the tip of the bone (Fig. 34). On the second digit about 2 mm. of cartilage surrounds the distal tip of the bone, distal

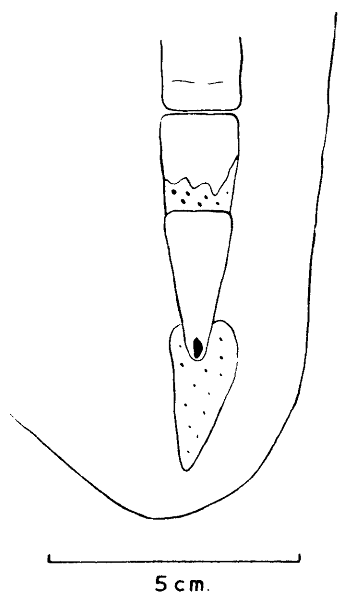


FIGURE 34

Terminal phalanx of the first digit of the fore flipper to show the lanceolate cartilage (cartilage dotted).

to the nail, but no cartilage could be found on the remaining digits. Such cartilaginous extensions on the fore flippers are well known in the Otariidae, but have not previously been reported from a phocid. This is understandable as most phocids have well developed claws on their fore flippers, and an extension of the soft tissue would serve little purpose. In Otariids, the middle three digits of the hind flipper combine both functional claws and cartilaginous extensions, and the extensions have to be bent back before the claws can be used.

Besides the Ross seal, only the leopard seal, with its slim 1 cm.-long claws, is beginning to show a reduction of these appendages. In this latter seal, the claws of digits 2–5 are at the free edge of the flipper but that of digit 1 is 2·5 cm. distant from it. It seems probable that the leopard seal would also have a cartilaginous support, but it has not been possible to verify this.

It has already been noted that no nail was found on the 5th digit of the fore flipper of the male seal. Digit 5 in this seal is composed of a metacarpal and proximal phalanx in the normal way, followed by a single bone a little larger than an intermediate phalanx, and rounded at its distal end (Fig. 33). Three collars of cartilage surround this bone, one at either end and one in the middle, but these lie in shallow depressions in the bone and are superficial to it, so that they are not visible radiographically. A very small cartilaginous nodule lies distal to this bone (Fig. 35).

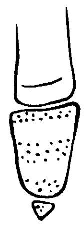


FIGURE 35

Diagram of the distal tip of the 5th digit of the fore flipper of the male seal, 1965·12·20·1 (cartilage dotted).

n. *Innominate.* The innominate bones articulate with the first sacral vertebra only. Their greatest overall length is 198 mm. in the male and 211 mm. in the female (199 mm. in male S1360). The ilium is short, thick, slightly everted but not excavated on its lateral surface—characters common to the ilia of all southern phocids. The eversion of the ilium is slightly more pronounced in the female, and consequently the anterior face is more extensive. The acetabulum is hemispherical with a deep acetabular fossa and notch, the latter bridged over by bone in the female. The post-acetabular part of the innominate is short and wide in the Ross seal, as Table VIII shows.

TABLE VIII

DIMENSIONS OF INNOMINATE (mm.)

	From centre of acetabulum to posterior end of innominate	*Width at level of ischiatic spine*	*Percentage*
O. rossi 1965·8·2·1 ♀	149	110	73·8
O. rossi 1965·12·20·1 ♂	128	101	78·9
O. rossi 324a	144	115	79·9
O. rossi S1360 ♂	132	99	75·0
Lobodon	157	119	75·8
Leptonychotes	176	107	60·8
Hydrurga	185	128	69·2
Mirounga	249	170	68·3

The ischium has a well developed spine. In the female the ischial margin curves from this spine smoothly to the posterior end of the innominate; in the male the dorsal margin is shallowly concave and meets the slightly convexly curved posterior margin roughly at right angles with, dorsally, a small eminence at the junction posterior to the ischiatic spine. This is probably associated with the attachment of the ischiocavernosus muscle of the penis. The pubis is much thicker and bulkier than has previously been noticed in any other seal, and is particularly large in the female, where its dorso-ventral width is 35 mm. (Fig. 36).

The innominate bones of the male and female seals described here can be distinguished, that of the female having a wider anterior face to the ilium, a rounded posterior edge to the ischium, and a more bulky pubis. But more specimens of each sex are needed before it can be ascertained whether these

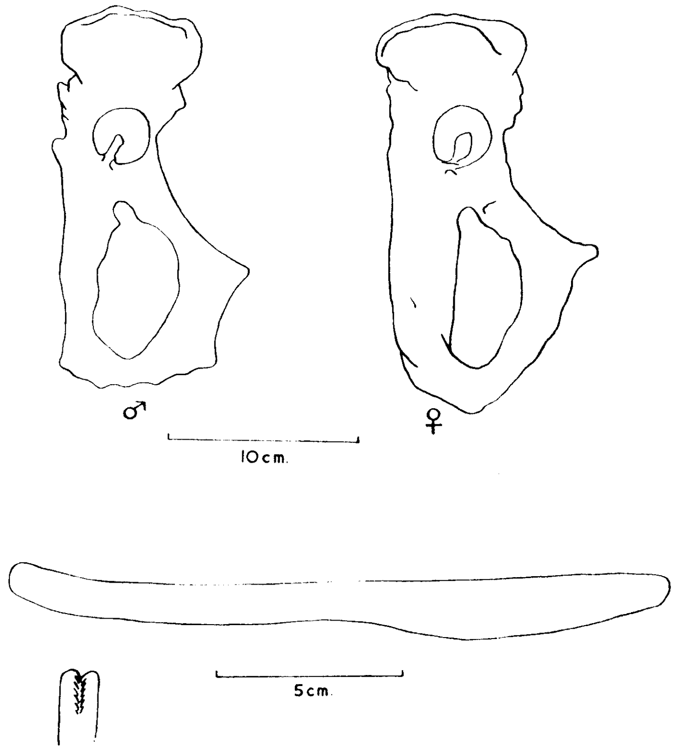


FIGURE 36

Innominate bones of the male (1965·12·20·1) and female (1965·8·2·1) seals.
Lateral view of the baculum and dorsal view of its distal end.

characters are invariably distinctive. The sex of the type specimen 324a is not known, but the innominate bones correspond very closely in shape with those of the female. The innominate bones of the male seal S1360 are very similar to those of the male 1965·12·20·1.

o. *Femur*. The femur (Fig. 37) is very short and flattened. Its shortness is shown in Table IX which gives the percentage of femoral length to tibial length. The greater trochanter is very broad antero-posteriorly, and hardly projects above the level of the neck, and is thus considerably below the level of the head. The shaft is so short that hardly more than a groove separates the lower part of the greater trochanter from the upper part of the rugosity of the lateral epicondyle. The medial epicondyle (Fig. 37a) is produced into a pronounced ridge which extends two-thirds of the way up the medial edge of the shaft. It has a concave anterior face and is considerably thicker and more prominent than in other Antarctic seals. No trochanteric fossa could be distinguished.

p. *Patella*. The patella is small and flattened with an oval articulating surface (Table X). It tapers slightly in thickness antero-posteriorly, and also from its medial to its lateral edge.

q. *Tibia and fibula* (Fig. 38). The tibia is fused with the head of the fibula proximally. The tibial crest

TABLE IX

DIMENSIONS OF FEMUR AND TIBIA (mm.)

	Ommatophoca	*Leptonychotes*	*Hydrurga*	*Lobodon*
Length of femur from head to tip of medial condyle	104*	117	143	143
Length of tibia from medial condyle to medial malleolus	281	269	308	292
Length of femur as percentage of length of tibia	37·0	43·5	46·4	48·9

* Length in specimen 1965·8·2·1. In specimens 1965·12·20·1 and 324a the length was 101 mm., and in S1360 104 mm.

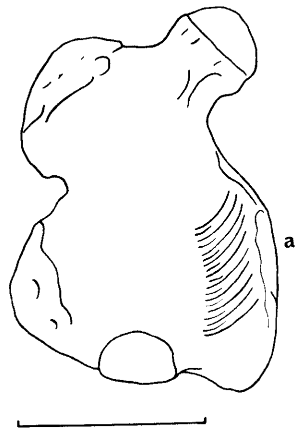


FIGURE 37

Anterior face of the right femur of 1965·12·20·1.
a. Medial epicondyle.

TABLE X
DIMENSIONS OF PATELLA (mm.)

Specimen	*1965·8·2·1* (female)	*1965·12·20·1* (male)	*S1360* (male)
Greatest length	25	21	24
Greatest width	27	27	25

is particularly feebly marked in *Ommatophoca* and *Mirounga*, and the anterior tibial fossa, which is shallow in all Antarctic phocids, is hardly visible in these two. The posterior surface, in *Ommatophoca*, has a well marked posterior tibial fossa.

The length of the tibia from the medial condyle to the medial malleolus is 281 mm. in specimen 1965·8·2·1, 242 mm. in 1965·12·20·1, 269 mm. in 324a, and 252 mm. in S1360.

r. *Tarsus*. The normal pinniped complement of tarsal bones is present (Fig. 38), and a limited comparison has been made with those of *Hydrurga*. As in the carpus, the pairs of articulating surfaces have been similarly labelled, and the differences between the Ross and leopard seal bones have been noted, even although their significance cannot yet be appreciated. (mt = metatarsus.)

The articulations of the Ross seal tarsus

A. tibia — astragalus
B. fibula — astragalus
C. fibula — calcaneum
D. astragalus — calcaneum (proximal)
E. astragalus — calcaneum (distal)
F. astragalus — navicular
G. astragalus — cuboid
H. calcaneum — cuboid
I. navicular — cuboid
J. navicular — external cuneiform*
K. external cuneiform — cuboid†
L. cuboid — mt 4‡
M. cuboid — mt 5
N. §
O. navicular — middle cuneiform
P. navicular — internal cuneiform
Q. external cuneiform — middle cuneiform
R. external cuneiform — mt 3 (on extensor side)
S. external cuneiform — mt 3 (on flexor side)
T. external cuneiform — mt 2
U. middle cuneiform — mt 2
V. middle cuneiform — internal cuneiform
W. internal cuneiform — mt 2
X. internal cuneiform — mt 1

* There is a second, smaller articulation between the navicular and the external cuneiform behind (towards the flexor side) the main one.
† In addition to the main proximal articulation (K) between the external cuneiform and the cuboid, there are two pairs of small flat articulations along the distal edges of the two bones.
‡ In addition to the main articulation of the cuboid with mt 4 (L), the cuboid just extends on to the edge of mt 3, in articulation S.
§ Inadvertently omitted.

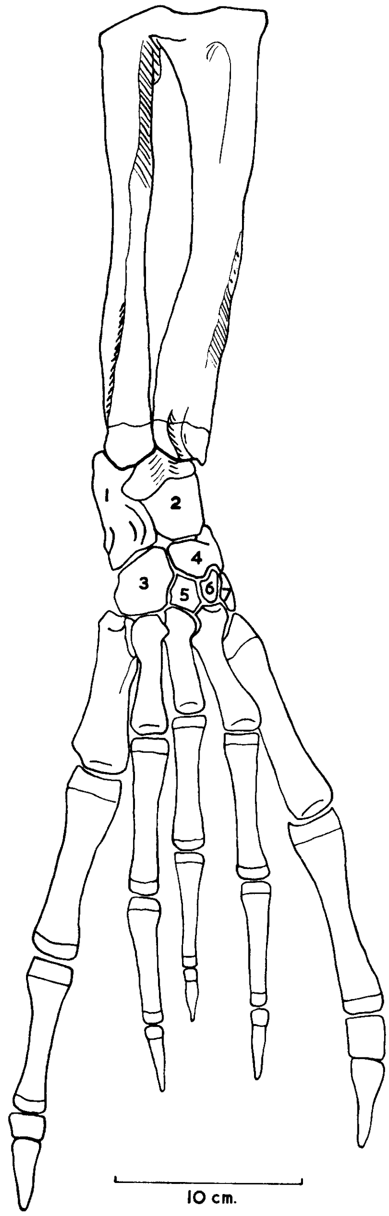


FIGURE 38

Lateral view of the right hind flipper of 1965·12·20·1.

1. Calcaneum, 2. Astragalus, 3. Cuboid, 4. Navicular, 5. External cuneiform, 6. Middle cuneiform, 7. Internal cuneiform.

Differences shown by the leopard seal tarsus

1. The tuber calcis is longer, whereas it is very short in the Ross seal.
2. The articulation between fibula and calcaneum (C) is large and obvious, but very small in the Ross seal.
3. There is no second smaller articulation between navicular and external cuneiform.
4. There are no extra articulations between external cuneiform and cuboid.
5. The cuboid does not extend on to mt 3.
6. The articulation O, between navicular and middle cuneiform, is almost flat in the leopard seal, but forms a distinct arc of a circle in the Ross seal.
7. The articulations between external cuneiform and mt 3 (R, S) form two distinct facets separated by 7 mm. in the leopard seal, but these are almost confluent in the Ross seal.

8. The articulation between internal cuneiform and mt 1 (W) is conspicuous in the leopard, but very small indeed in the Ross seal.

There are other differences in the precise shape and inclination of the various articulations, but as noted above, a detailed comparison has not been attempted.

s. *Pes*. The general shape of the Ross seal pes is that typical of southern phocids (King, 1966). The third metatarsal is short, reducing the length of this digit. The first metatarsal is considerably elongated, and all bones of the two outer digits are strong. The flatter phalangeal bones, and the shape of the interphalangeal articulations are those characteristic of southern phocids generally.

The elongated epiphyses of the terminal phalanges (Plate Xb), which are similar to those of the manus, have already been described (King, 1965). The terminal phalanges distal to the epiphyses are flattened, triangular bones, faintly marked where the small nail nodules are attached. Their dimensions are given in Table XI.

TABLE XI

DIMENSIONS OF TERMINAL PHALANGES OF PES (mm.)

Specimen	*1965·8·2·1* (female)					*1965·12·20·1* (male)				
Digit	1	2	3	4	5	1	2	3	4	5
Length of terminal phalanx including epiphysis	77	44	35	42	57	65	41	31	35	47
Length of epiphysis	33	14	10	12	19	25	9	8	8	15

It has not yet been possible to obtain an adequate series of phocid hind flippers of an appropriate age for comparison, but in *Pagophilus*, *Halichoerus* and *Cystophora*, at least, similarly elongated epiphyses may be found in the hind flipper, mainly on the 1st, or 1st and 5th digits. They seem, however, to be most developed in *Hydrurga* and *Ommatophoca* where fusion is delayed as in the manus.

Although infrequently mentioned, cartilaginous extensions to the tips of the hind digits are known in some Phocidae, and are, according to Leboucq (1904*b*), developed in inverse proportion to the development of the nail. They are easily demonstrated in the hind flipper of *Ommatophoca* (Fig. 39). That of the 1st digit is longest; it is lanceolate, extending 5 cm. beyond the tip of the bone, and approximately 2 cm. up the outer side. Near the tip of the phalanx the cartilage is 6 mm. thick, but it quickly tapers to about 1·5 mm. The cartilage of the 5th digit is smaller, 3 cm. in overall length and roughly rectangular in shape; those of the middle three digits are lanceolate and about 1·5 cm. in length. The cartilage, particularly of the outer digits, is pierced by large vascular channels, and the tips of the flippers also give every appearance of being well vascularized.

On the plantar surface, the flexor tendons were traced beyond the tips of the terminal phalanges and into the cartilage. The smaller cartilages had tendons extending at least as far as their proximal ends, and on the large cartilage of the 1st digit the tendon was easily visible 2·5 cm. beyond the tip of the bone after which the fibres became too fine to be easily traced. Leboucq (1904*b*) also draws attention (Fig. 39a) to the prolongation of the flexor tendon into the cartilage. In the discussion to his paper he quotes Roux as saying that this arrangement of the tendons would assist in preventing the more flexible tips of the flippers from being bent too far backwards while swimming.

III. CONCLUSIONS

The many peculiarities and diversities of structure that have come to light during the work on the Ross seal are mainly concerned with swimming, with the location, capture and eating of food and, probably, with the appreciation of sound.

There are indications of a progressive specialization towards a more flipper-like fore limb within the Monachinae, including the diminution in size of the nails, the reduction in length of the 5th digit and the increase in length of the 1st digit (King, 1964). *Ommatophoca* is probably the most advanced of the phocids in this respect, and in addition has elongated epiphyses and cartilaginous extensions that further

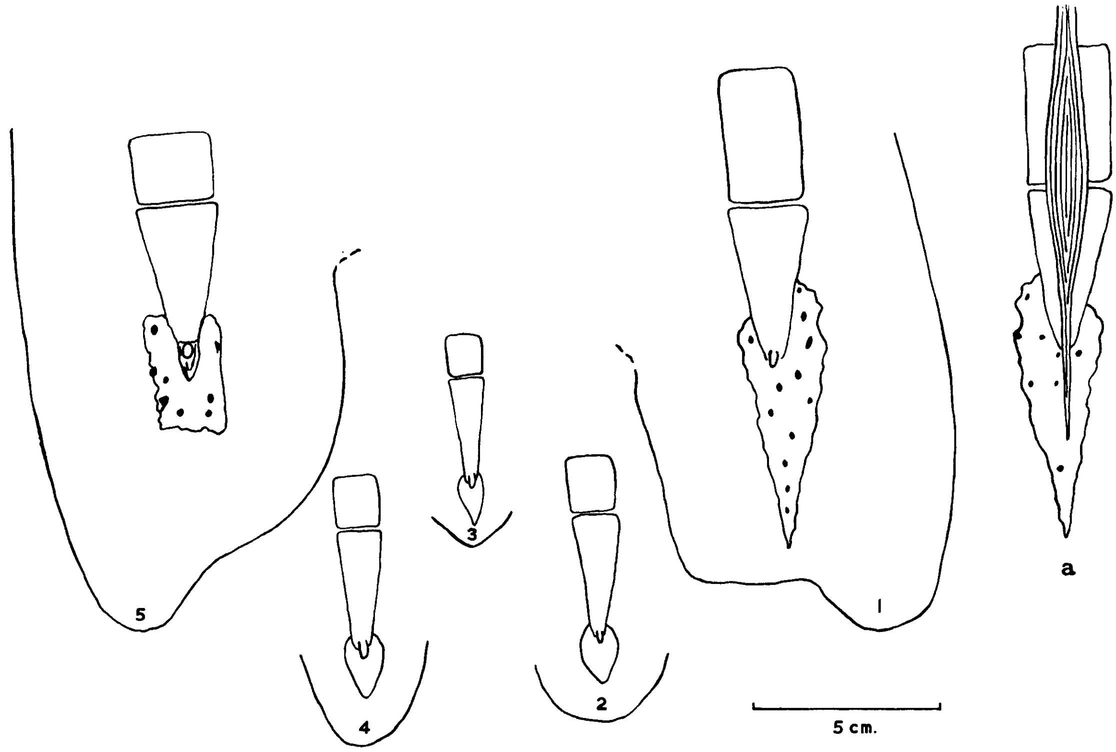


FIGURE 39

Lateral view of the terminal phalanges of the left hind flipper (digits numbered) showing the cartilaginous extensions of the digits.
a. Medial view of the tip of the 1st digit to show the extent of the flexor tendon.

increase the length of the flipper in general and of the 1st digit in particular. Differences in the osteology of the fore flipper are difficult to explain without reference to the myology, but it is obvious that the movement of the fore flipper in *Ommatophoca* is different from that in *Halichoerus* and *Phoca*, for example, and is probably closer to that of *Zalophus* where a more positive swimming action is used.

Many of the other specializations of *Ommatophoca* are directed towards dealing with its food and these have been mentioned in the discussion on the throat and jaw muscles. The shape of the tracheal cartilages also comes into this category. The modification of the nasal cartilages, to form a very efficient protection against the entry of water, and the very large eyeballs may be counted as advantageous in diving and in the appreciation of the underwater environment.

The laryngeal and auditory specializations are less easy to explain. Little work has so far been done on the sounds produced by *Ommatophoca*, and even less on its hearing capabilities. Some of the characters of the middle ear and auditory tube may be concerned with the protection of the ear against increased pressure during deep diving.

It should perhaps be remembered that although many of these characters have been seen first in *Ommatophoca*, they may not all be peculiar to this genus. Our knowledge of the anatomy of the other closely related Antarctic seals is very meagre, and it may well be that they too possess some of these modifications.

IV. ACKNOWLEDGEMENTS

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The Australian Museum, Sydney, the South Australian Museum, Adelaide, and the National Museum of Victoria, Melbourne, made me welcome while I measured specimens.

My colleagues Dr. W. G. Inglis and Mr. S. Prudhoe identified the parasites; the British Museum photographers took many excellent photographs at short notice; Professor H. R. Hewer provided the information on ageing; Dr. S. Saunders allowed me to use his notes on the eye; Mr. D. W. Yalden gave much help in the interpretation of the carpus; and Professor A. J. E. Cave also gave me advice and assistance. To all these people I am much indebted.

Some of the parts of these two seals—flippers, kidneys, reproductive organs—are being reported on by other workers, and it is hoped that their papers will be published either in this series or in the *British Antarctic Survey Bulletin*. The present author is grateful for the specialist attention which these parts are receiving.

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APPENDICES

A. Body Measurements

B. Body Weights

C. Skull Measurements and Proportions

APPENDIX A
BODY MEASUREMENTS OF THE ROSS SEAL

	♀ *Specimen 1965·8·2·1*		♂ *Specimen 1965·12·20·1*	
	(in.)	(cm.)	(in.)	(cm.)
Tip of nose to tip of tail	90·50	230·0	79·00	201·0
Tip of tail to tip of hind flipper	18·00	45·7	11·50	29·2
Tip of nose to tip of fore flipper	—	—	40·00	101·5
Tip of tail to anus	—	—	6·50	16·5
Distance between teats	5·00	12·7	—	—
Vulva to teats (in mid line)	20·50	52·1	—	—
Teats to umbilicus (in mid line)	3·25	8·2	—	—
Tip of nose to penile opening	—	—	53·00	134·6
Umbilicus to penile opening	—	—	4·75	12·1
Anus to penile opening	—	—	7·00	17·7
Length of palpebral fissure	1·25	3·2	1·37	3·5
Length of mouth margin	7·50	18·1	8·25	20·9
Greatest width of mouth, transverse	—	—	4·75	12·1
Distance between eyes at anterior canthi	3·25	8·2	5·70	14·7
Tip of snout to anterior canthus of eye	4·50	11·4	4·20	10·6
Length of nostril	1·50	3·8	1·10	2·7
Ear to centre of eye	1·70	4·3	2·50	6·5
Ear to anterior canthus of eye	2·20	5·7	3·30	8·3
Ear to posterior canthus of eye	1·20	3·0	1·90	4·8
Ear to tip of snout	6·75	17·1	7·40	18·8
Blubber thickness:				
mid ventral (2 in. cranial to umbilicus)	0·70	1·8	1·20	3·0
lateral	1·00	2·5	—	—
mid ventral between insertions of fore flippers	—	—	1·50	3·8
Alimentary canal, total length (in ft. and m.)*	45·83*	13·96*	34·90*	10·64*
oesophagus	*c.* 48·00	121·9	38·4	100·0
stomach and duodenum	17·00	43·2	—	—
small intestine (in ft. and m.)*	37·00*	11·27*	—	—
large intestine and rectum	41·00	104·1	—	—
stomach to anus (in ft. and m.)*	—	—	31·58*	9·64
Diameter of posterior vena cava	2·00	5·1	—	—
Fore flipper:				
length, along curve of longest digit, from junction with body to tip	17·00	43·20	12·75	32·40
width when closed†	5·25	13·30	4·50	11·40
width when expanded†	8·37	22·20	5·00	12·70
spread‡	11·50	29·20	8·00	20·30
tip of longest digit to upper end metacarpal	12·50	31·70	10·00	25·40
distance of nail from tip of flipper on 1st digit	1·50	3·80	1·37	3·50
distance of nail from tip of flipper on 2nd digit	0·50	1·27	0·37	0·95
distance of nail from tip of flipper on 3rd digit	0·37	0·95	0·25	0·63
distance of nail from tip of flipper on 4th digit	0·37	0·95	0·12	0·32
distance of nail from tip of flipper on 5th digit	0·75	1·90	—	—
Hind flipper				
width of flipper when closed§	—	—	6·10	15·50
width of flipper when expanded§	—	—	13·70	35·00
distance of nail from tip of flipper on 1st digit	2·90	7·50	1·90	5·00
distance of nail from tip of flipper on 2nd digit	1·00	2·50	0·59	1·50
distance of nail from tip of flipper on 3rd digit	0·59	1·50	0·39	1·00
distance of nail from tip of flipper on 4th digit	1·00	2·50	0·59	1·50
distance of nail from tip of flipper on 5th digit	2·90	7·50	1·50	4·00

* All measurements are in in. and cm. except the total length of the alimentary canal, the length from stomach to anus, and the length of the small intestine which are given in ft. and m.

† Taken at the level of the nail of the shortest digit, at right angles to the leading edge.

‡ Taken along the line of the nails. § Taken between the outside edges of the outer digits.

APPENDIX B

BODY WEIGHTS OF THE ROSS SEAL

	♀ Specimen 1965·8·2·1		♂ Specimen 1965·12·20·1	
	(lb. oz.)	(kg.)	(lb. oz.)	(kg.)
Entire animal, frozen	399 lb. 15·0 oz.	181·800	384 lb. 2·0 oz.	174·600
Kidney (right)	1 lb. 11·5 oz.	0·780	9·9 oz.	0·280
Kidney (left)	—	—	10·2 oz.	0·290
Both kidneys and posterior vena cava	3 lb. 10·0 oz.	1·648	—	—
Lung (left)	39 lb. 0·1 oz.	19·504	—	—
Both lungs and 24·15 cm. trachea	—	—	5 lb. 4·8 oz.	2·410
Pancreas	8·8 oz.	0·250	—	—
Spleen	9·3 oz.	0·263	8·3 oz.	0·235
Thyroid	0·6 oz.	0·016	0·3 oz.	0·010
Suprarenal (right)	0·6 oz.	0·018	0·6 oz.	0·018
Suprarenal (left)	0·7 oz.	0·021	0·5 oz.	0·015
Heart and aorta	—	—	1·4 oz.	1·400
Testis (right)	—	—	2·8 oz.	0·080
Testis (left)	—	—	3·0 oz.	0·085

KEY TO APPENDIX C

*Ship	Expedition
Aurora	Australian National Antarctic Expedition, 1911–14.
Belgica	Belgian Antarctic Expedition, 1897–99.
Gauss	German South Polar Expedition, 1901–03. (See footnote on p. 3.)
Discovery	British National Antarctic Expedition, 1901–04.
Discovery II	"Discovery" Investigations, 6th voyage, 1950–51.
Erebus and Terror	British Expedition, 1839–43.
Kista Dan	British Antarctic Survey, 1962–63.
Nimrod	British Antarctic Expedition, 1907–09.
Norsel	Norwegian–British–Swedish Expedition, 1949–52.
Scotia	Scottish National Antarctic Expedition, 1902–04.
Southern Cross	British Antarctic Expedition, 1898–1900.
Thala Dan	Australian National Antarctic Research Expedition, 1961–62.

†Museums	
Adelaide	The South Australian Museum, Adelaide.
Berlin	Zoologisches Museum der Universität, Berlin N4.
BM (NH)	British Museum (Natural History), London.
Brussels	Institut Royal des Sciences Naturelles de Belgique, Brussels.
Melbourne	National Museum of Victoria, Melbourne.
Roy. Scot. Mus.	Royal Scottish Museum, Edinburgh.
Sydney	The Australian Museum, Sydney.

‡ Estimate.
§ No jugals.
|| 897 of Barrett-Hamilton.
** 700 of Barrett-Hamilton.
†† Parts missing.
‡‡ Skull collected from Chick Island, Antarctica, 22 January 1962. Presented by Dr. P. G. Law.

*Expedition ship**	*Registered number of specimen*	*Museum†*	*Sex*	*Condylobasal length*		*Interorbital width*		*Snout length*		*Snout width at zygomatic*	
				(mm.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)
Norsel	1961·2·24·6	BM (NH)	♂	169‡	100	44	26·0	50	29·6	56	33·1
Discovery	1908·2·20·49	BM (NH)	♂	220	100	47	21·4	61	27·7	63	28·6
? Nimrod	1949·2·3·2	BM (NH)	–	223	100	47	21·1	63	28·3	69	30·9
Aurora	M2506	Sydney	♂	228	100	51	22·4	67	29·4	78	34·2
Discovery	1907·85·2	Roy. Scot. Mus.	♂	231	100	46	19·9	67	29·0	64	27·7
Southern Cross	1901·1·4·13	BM (NH)	–	233	100	51	21·9	67	28·8	72	30·9
Belgica	1164a‖	Brussels	♂	233	100	40	17·2	61	26·2	69	29·6
Scotia	2	Roy. Scot. Mus.	♀	236‡	100	49	20·8	68	28·8	72	30·5
Norsel	1961·2·24·3	BM (NH)	♂	236	100	44	18·6	63	26·7	74	31·4
Discovery	1908·2·20·50	BM (NH)	♂	237‡	100	44	18·6	63	26·6	70	29·5
Erebus and Terror	1843·11·16·7 (324b)	BM (NH) Type	–	237	100	47	19·8	68	28·7	73	30·8
Aurora	C7298	Melbourne	♀	240‡	100	49	20·4	69	28·8	79	32·9
Norsel	1961·2·24·2	BM (NH)	♂	242	100	56	23·1	72	29·8	81	33·5
Thala Dan	C7354‡‡	Melbourne	♂	246	100	44	17·9	67	27·2	76	30·9
Discovery	1908·2·20·48	BM (NH)	♂	247	100	43	17·4	75	30·4	74	29·9
Discovery	1908·2·20·47	BM (NH)	♂	247	100	46	18·6	70	28·3	78	31·6
Kista Dan	1965·12·20·1	BM (NH)	♂	248	100	—	—	73	29·4	71	28·6
Norsel	1961·2·24·9	BM (NH)	♂	249	100	47	18·9	73	29·3	69	27·7
Aurora	M306	Adelaide	♂	250	100	54	21·6	69	27·6	78	31·2
Scotia	43	Roy. Scot. Mus.	♂	250	100	44	17·6	69	27·6	80	32·0
Southern Cross	1901·1·4·12	BM (NH)	–	250	100	44	17·6	73	29·2	77	30·8
Norsel	1961·2·24·7	BM (NH)	♂	252	100	46	18·3	66	26·2	77	30·6
Kista Dan	1965·8·2·1	BM (NH)	♀	254	100	52	20·5	70	27·6	70	27·6
Southern Cross	1949·2·3·1	BM (NH)	–	254	100	49	19·3	74	29·1	83	32·7
Erebus and Terror	1843·11·25·4 (324a)	BM (NH) Type	–	254	100	52	20·8	74	29·1	77	30·3
Norsel	1961·2·24·1	BM (NH)	♂	254	100	55	21·7	73	28·7	80	31·5
Norsel	1961·2·24·10	BM (NH)	♂	254	100	55	21·7	72	28·3	74	29·1
Norsel	1961·2·24·8	BM (NH)	♂	255	100	45	17·6	74	29·0	82	32·2
Aurora	S1360	Sydney	♂	256	100	54	21·1	77	30·1	77	30·1
Belgica	1164c**	Brussels	♀	256	100	48	18·8	74	28·9	77	30·1
Norsel	1961·2·24·5	BM (NH)	♂	257	100	51	19·8	75	29·2	75	29·2
Discovery II	1951·4·24·1	BM (NH)	–	263	100	59	22·4	79	30·0	78	29·7
Deutschland	36245	Berlin	♂	264	100	51	19·3	75	28·4	80	30·3
Norsel	1961·2·24·4	BM (NH)	♂	265	100	49	18·6	56	21·2	80	30·3

APPENDIX C

SKULL MEASUREMENTS AND PROPORTIONS

Interorbital width		*Snout length*		*Snout width at zygomatic*		*Snout width at canines*		*Palate length*		*Nasals length*		*Nasals width anteriorly*		*Zygomatic width*		*Mastoid width*	
m.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)
44	26·0	50	29·6	56	33·1	34	20·1	68	40·2	58	34·3	17	10·1	133‡	78·7	—	—
47	21·4	61	27·7	63	28·6	39	17·7	78	35·5	64	29·1	22	10·0	161	73·2	159	72·3
47	21·1	63	28·3	69	30·9	35	15·7	74	33·2	62	27·8	22	9·9	170	76·2	166	74·4
51	22·4	67	29·4	78	34·2	41	17·9	68	29·8	72	31·6	25	10·9	167	73·2	159	59·7
46	19·9	67	29·0	64	27·7	42	18·2	87	37·7	59	25·5	19	8·2	162	70·1	159	68·8
51	21·9	67	28·8	72	30·9	43	18·5	84	36·1	68	29·2	32	13·7	179	76·8	169	72·5
40	17·2	61	26·2	69	29·6	40	17·2	74	31·8	55	23·6	26	11·2	155	66·5	152	65·2
49	20·8	68	28·8	72	30·5	44	18·6	86	36·4	55	23·3	27	11·4	170‡	72·0	—	—
44	18·6	63	26·7	74	31·4	43	18·2	80	33·9	69	29·2	26	11·0	174	73·7	169	71·6
44	18·6	63	26·6	70	29·5	38	16·0	73	30·8	66	27·8	28	11·8	173	72·9	167	70·5
47	19·8	68	28·7	73	30·8	42	17·7	90	37·9	66‡	27·8	21‡	8·9	167	70·5	160	67·5
49	20·4	69	28·8	79	32·9	42	17·5	77	32·1	59	24·6	28	11·7	169	70·4	—	—
56	23·1	72	29·8	81	33·5	46	19·0	84	34·7	67	27·7	31	12·8	178	73·6	171	70·7
44	17·9	67	27·2	76	30·9	45	18·3	75	30·5	77	31·3	25	10·2	172	69·9	164	66·7
43	17·4	75	30·4	74	29·9	44	17·8	78	31·6	58	23·5	28	11·3	174	70·4	172	69·6
46	18·6	70	28·3	78	31·6	42	17·0	85	34·4	47	19·0	29	11·7	181	73·3	164	66·4
—	—	73	29·4	71	28·6	49	19·8	90	36·3	66	26·6	26	10·5	182	73·4	179‡	72·2
47	18·9	73	29·3	69	27·7	48	19·3	91	36·5	65	26·1	28	11·2	186	74·7	163	65·5
54	21·6	69	27·6	78	31·2	43	17·2	76	30·4	82	32·8	29	11·6	175	70·0	160	64·0
44	17·6	69	27·6	80	32·0	47	18·8	83	33·2	74	29·6	29	11·6	180	72·0	172	68·8
44	17·6	73	29·2	77	30·8	46	18·4	85	34·0	63	25·2	27	10·8	184	73·6	169	67·6
46	18·3	66	26·2	77	30·6	42	16·7	82	32·5	69	27·4	25	9·9	172	68·3	159	63·1
52	20·5	70	27·6	70	27·6	45	17·7	85	33·5	74	29·1	27	10·6	180	70·9	162‡	63·8
49	19·3	74	29·1	83	32·7	47	18·5	82	32·3	53	20·9	26	10·2	176	69·3	167	65·7
52	20·8	74	29·1	77	30·3	44	17·3	87	34·3	79	31·1	32	12·6	182	71·7	171	67·3
55	21·7	73	28·7	80	31·5	47	18·5	84	33·1	62	24·4	31	12·2	178	70·1	166	65·4
55	21·7	72	28·3	74	29·1	45	17·7	72	28·3	72	28·3	22	8·7	184	72·4	163	64·2
45	17·6	74	29·0	82	32·2	51	20·0	85	33·3	52	20·4	25	9·8	186	72·9	176	69·0
54	21·1	77	30·1	77	30·1	44	17·2	78	30·5	73	28·5	30	11·7	188	73·4	171	66·8
48	18·8	74	28·9	77	30·1	48	18·8	86	33·6	77	30·1	24	9·4	172	67·2	167	65·2
51	19·8	75	29·2	75	29·2	48	18·7	94	36·6	69	26·8	31	12·1	182	70·8	168	65·4
59	22·4	79	30·0	78	29·7	47	17·9	96	36·5	59	22·4	32	12·2	190	72·2	175	66·5
51	19·3	75	28·4	80	30·3	46	17·4	92	34·8	63	23·9	28	10·6	190	71·9	173	65·5
49	18·6	56	21·2	80	30·3	48	18·2	86	32·6	80	30·3	26	9·8	177	67·0	162	61·4

…sals width …nteriorly		*Zygomatic width*		*Mastoid width*		*Orbit length*		*Skull weight (no jaw)*	*Anterior fontanelle*	*Suture age*	*Nose–tail length of body*
…n.)	(%)	(mm.)	(%)	(mm.)	(%)	(mm.)	(%)				
7	10·1	133‡	78·7	—	—	57	33·7	—	widely open	9‡	130 cm.
2	10·0	161	73·2	159	72·3	70	31·8	0·49 kg.	position visible	10	180 cm.
2	9·9	170	76·2	166	74·4	71	31·8	0·56 kg.	position visible	17	—
5	10·9	167	73·2	159	59·7	67	29·4	—	widely open	15	188 cm.
0	8·2	162	70·1	159	68·8	71	30·7	0·59 kg.	widely open	21	213 cm.
2	13·7	179	76·8	169	72·5	—	—	0·64‡kg.§	slightly open	17	—
5	11·2	155	66·5	152	65·2	70	30·0	0·59 kg.	slightly open	15	—
7	11·4	170‡	72·0	—	—	72	30·5	—	position visible	—	229 cm.
5	11·0	174	73·7	169	71·6	76	32·2	0·72 kg.	position visible	18	254 cm.
3	11·8	173	72·9	167	70·5	69	29·1	—	widely open	—	198 cm.
1‡	8·9	167	70·5	160	67·5	70	29·5	0·61 kg.	position visible	18	—
3	11·7	169	70·4	—	—	73	30·4	—	broken	—	—
1	12·8	178	73·6	171	70·7	72	29·8	0·99 kg.	widely open	21	260 cm.
5	10·2	172	69·9	164	66·7	78	31·7	—	shut	20	—
3	11·3	174	70·4	172	69·6	77	31·2	0·78 kg.	position visible	20	223 cm.
0	11·7	181	73·3	164	66·4	71	28·7	0·76 kg.	widely open	20	236 cm.
5	10·5	182	73·4	179‡	72·2	79	31·9	—	—	—	201 cm.
3	11·2	186	74·7	163	65·5	75	30·1	0·71 kg.	slightly open	22	231 cm.
0	11·6	175	70·0	160	64·0	74	29·6	—	shut	14	204 cm.
0	11·6	180	72·0	172	68·8	77	30·8	0·65 kg.	widely open	14	227 cm.
7	10·8	184	73·6	169	67·6	73	29·2	0·69 kg.	position visible	19	—
5	9·9	172	68·3	159	63·1	77	30·6	0·66 kg.	slightly open	17	279 cm.
7	10·6	180	70·9	162‡	63·8	78	30·7	—	—	—	230 cm.
5	10·2	176	69·3	167	65·7	76	29·9	0·62 kg.	slightly open	20	—
2	12·6	182	71·7	171	67·3	76	29·9	0·74‡kg.††	slightly open	—	—
1	12·2	178	70·1	166	65·4	73	28·7	0·92 kg.	widely open	20	268 cm.
2	8·7	184	72·4	163	64·2	81	31·9	0·78 kg.	widely open	16	—
5	9·8	186	72·9	176	69·0	76	29·8	0·75 kg.	widely open	22	246 cm.
0	11·7	188	73·4	171	66·8	77	30·1	—	widely open	14	199 cm.
4	9·4	172	67·2	167	65·2	81	31·6	1·03 kg.	slightly open	19	—
1	12·1	182	70·8	168	65·4	78	30·4	1·03 kg.	widely open	19	246 cm.
2	12·2	190	72·2	175	66·5	76	28·9	0·91 kg.	slightly open	21	213 cm.
3	10·6	190	71·9	173	65·5	77	29·2	0·95 kg.	widely open	20	—
5	9·8	177	67·0	162	61·4	71	26·9	0·82 kg.	widely open	20	300 cm.

[*face p. 54*

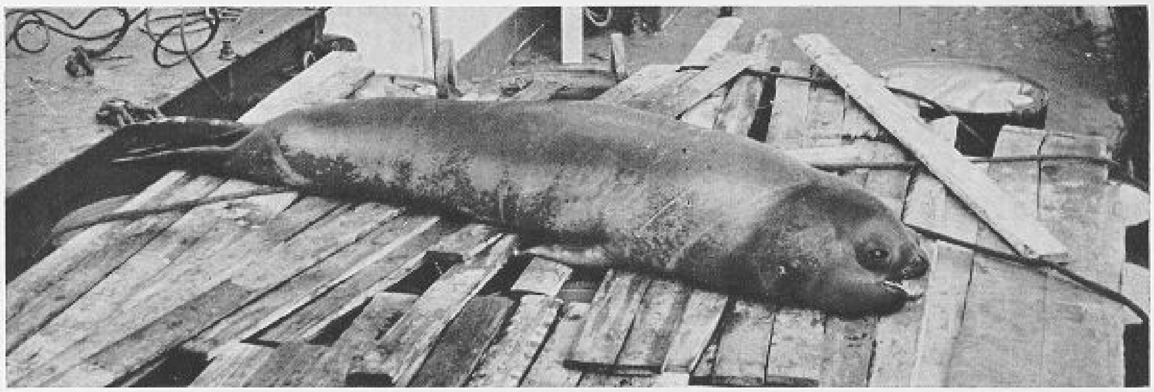
PLATE I

a. *Ommatophoca rossi* female photographed on board M.V. *Kista Dan*.

b. Lateral view of the head.

c. Dorsal view of the head.

(Photographs: M. Thurston, British Antarctic Survey)



a

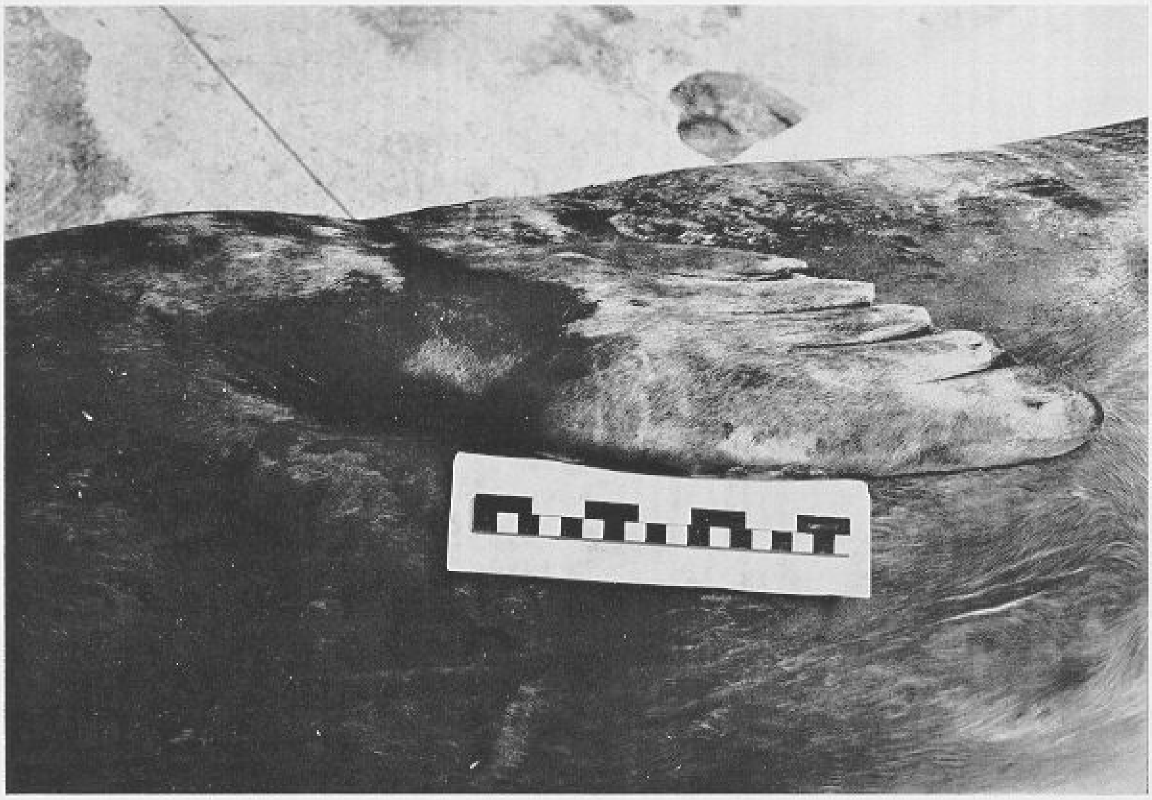
b

c

PLATE II

a. Ventro-lateral view of the left fore flipper of the female seal. (Photograph: London Hospital Medical College)

b. Part of the right fore flipper (female) showing the nails. (Photograph: BM(NH))



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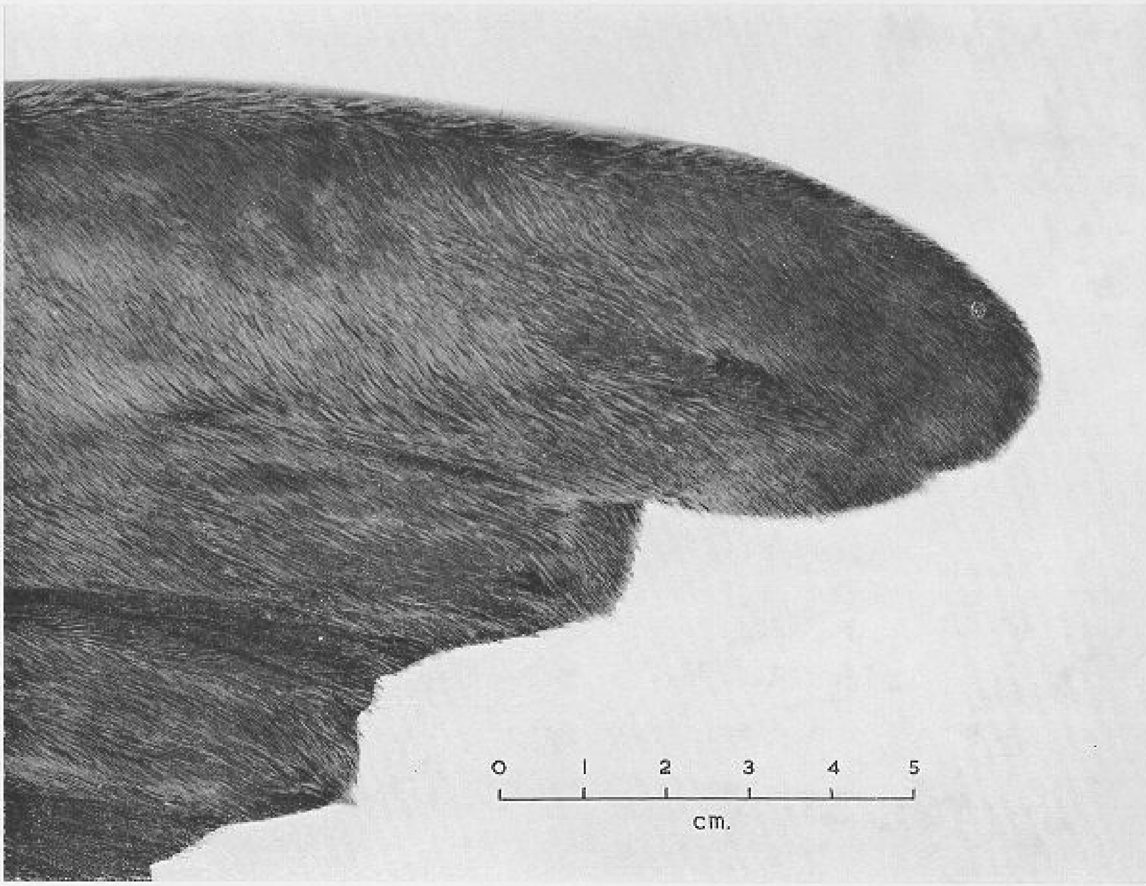
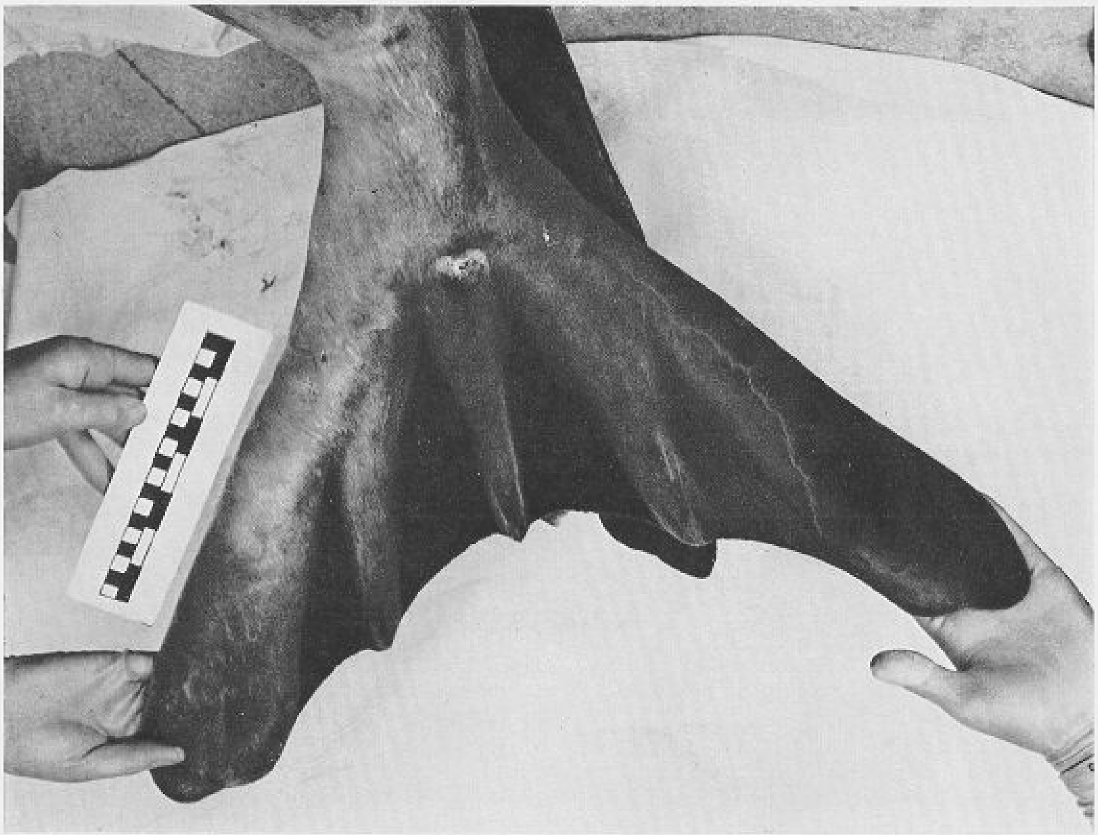


b

PLATE III

a. External surface of the expanded left hind flipper (female). (Photograph: London Hospital Medical College)

b. Ventral surfaces of the hind flippers and tail (male). (Photograph: BM (NH))



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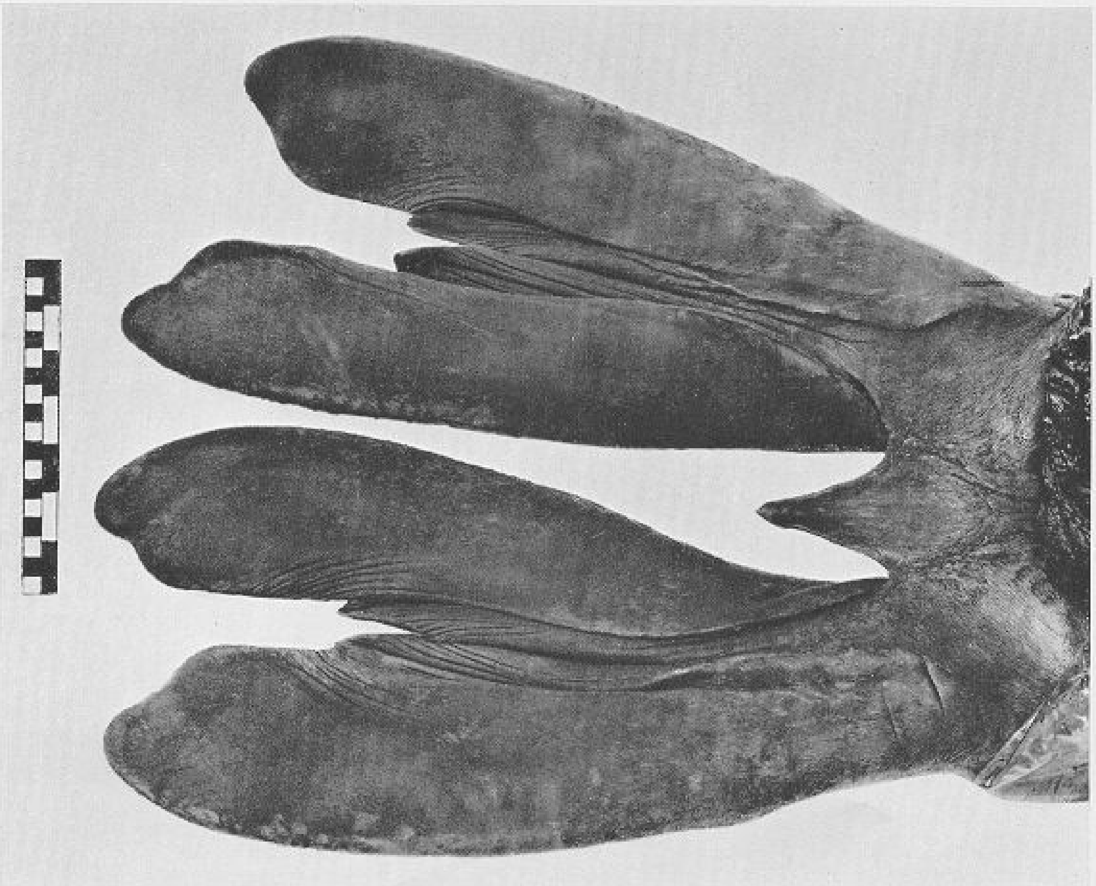


b

PLATE IV

The partially dissected head (female) showing the eyeball in its natural position in the orbit. The small dark rectangle just posterior to the eye is a piece of the external skin with the external auditory meatus in it. This is in its natural position, and posterior to it can be seen the auditory tube.
(Photograph: BM(NH))

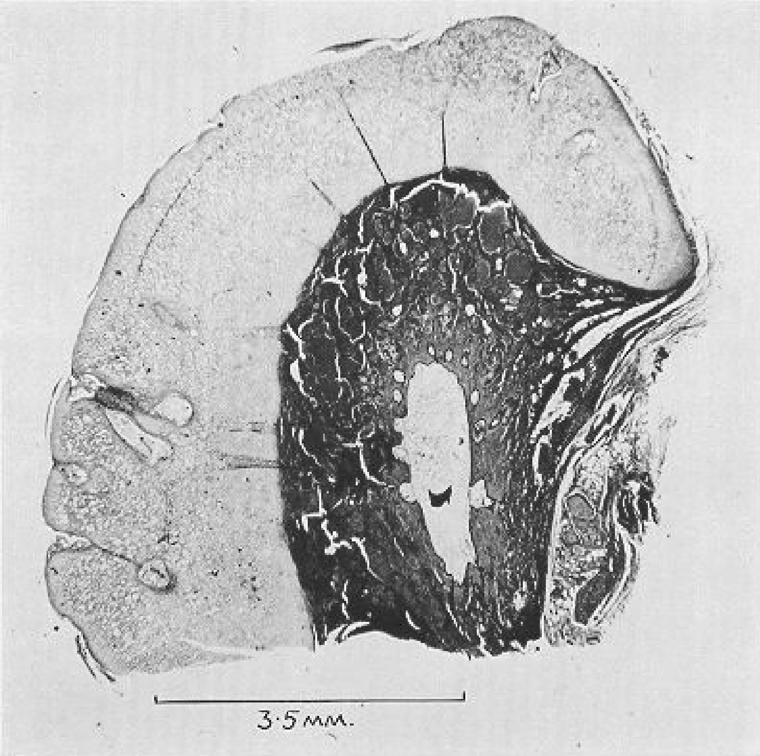
PLATE V

a. Section through the external auditory meatus (female). It was taken close to the skull, so the cartilage does not extend all the way round.

b. Section through the vascular thickening of the middle ear lining of *Phoca vitulina*.

c. Section through the thin part of the middle ear lining of *Ommatophoca* (female).

d. Section through the vascular thickening of the middle ear lining of *Ommatophoca* (female).
(Photographs: BM(NH))



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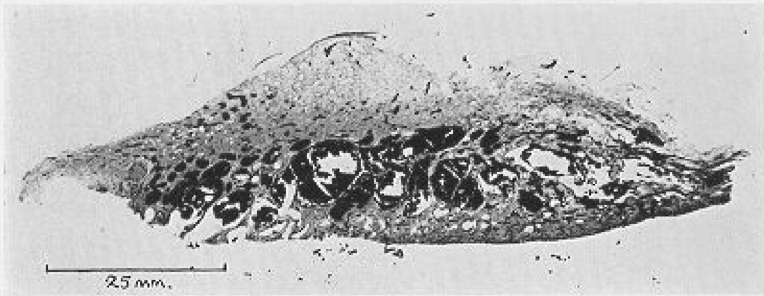

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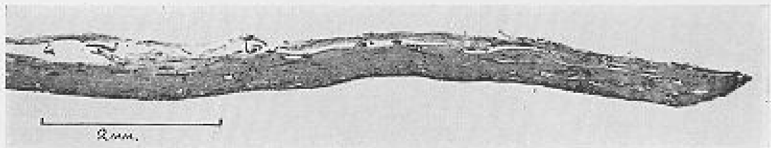

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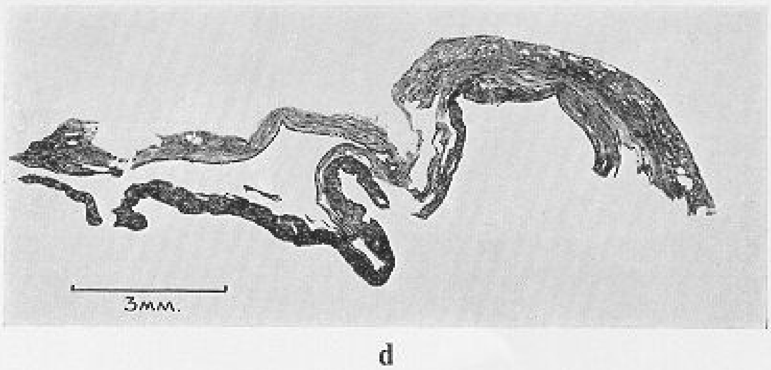
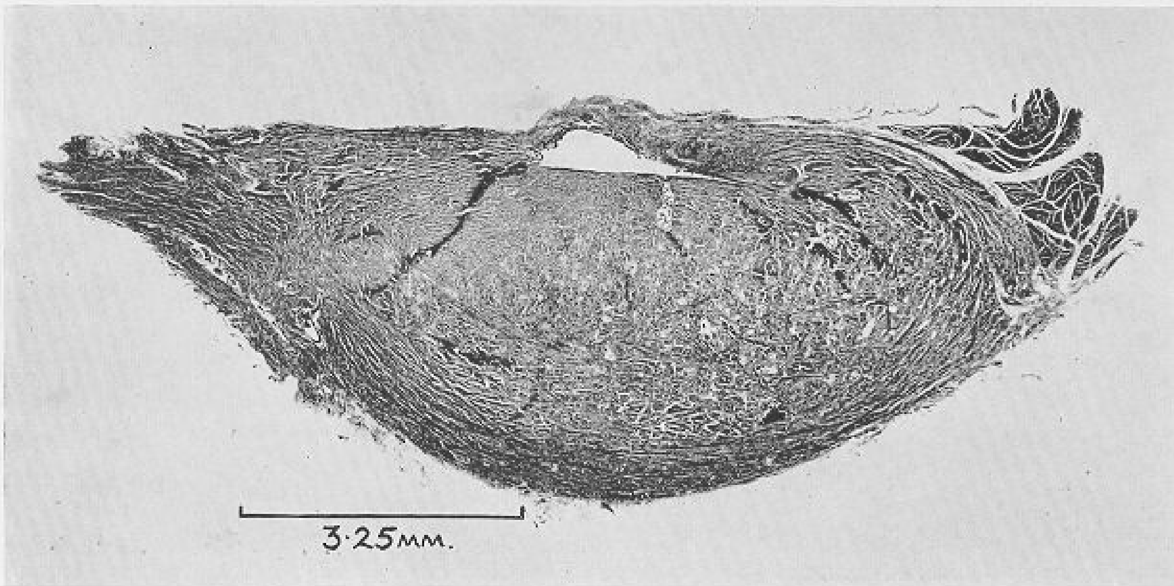


d

PLATE VI

a. Section through the Eustachian tube of female *Ommatophoca*. The lumen is dorsal, and part of the levator palati muscle can be seen on the right.

b. Section through the Eustachian tube of *Phoca vitulina*. The lumen is lateral, with cartilage internal to it.
(Photographs: BM(NH))



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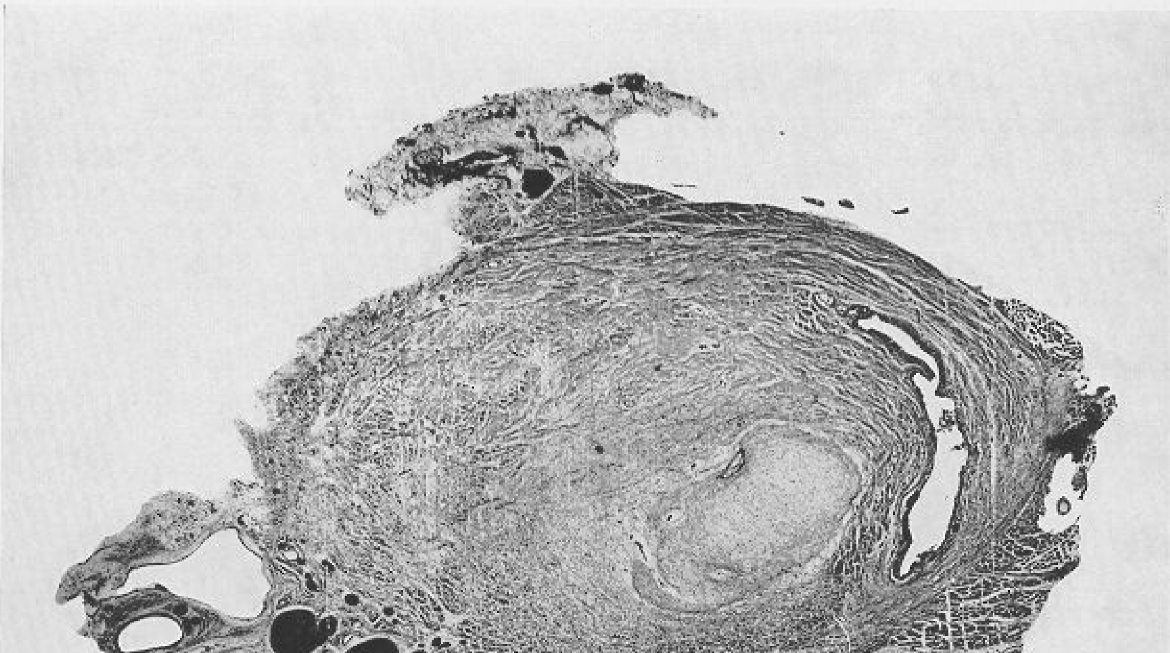

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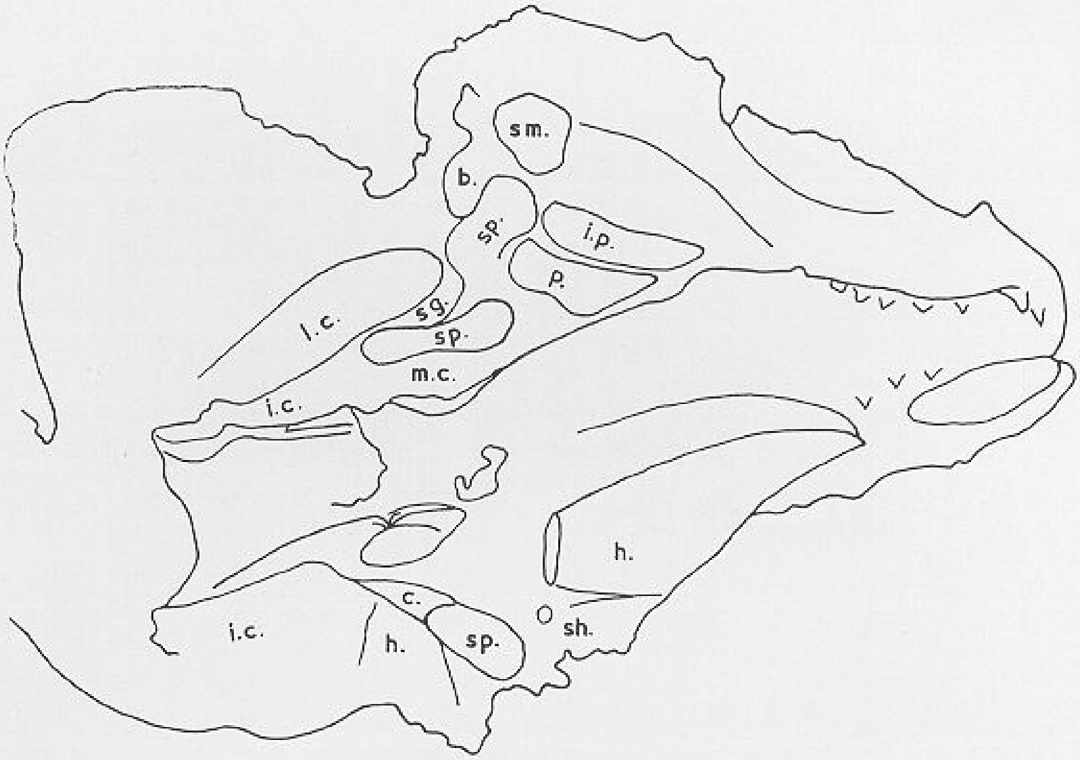
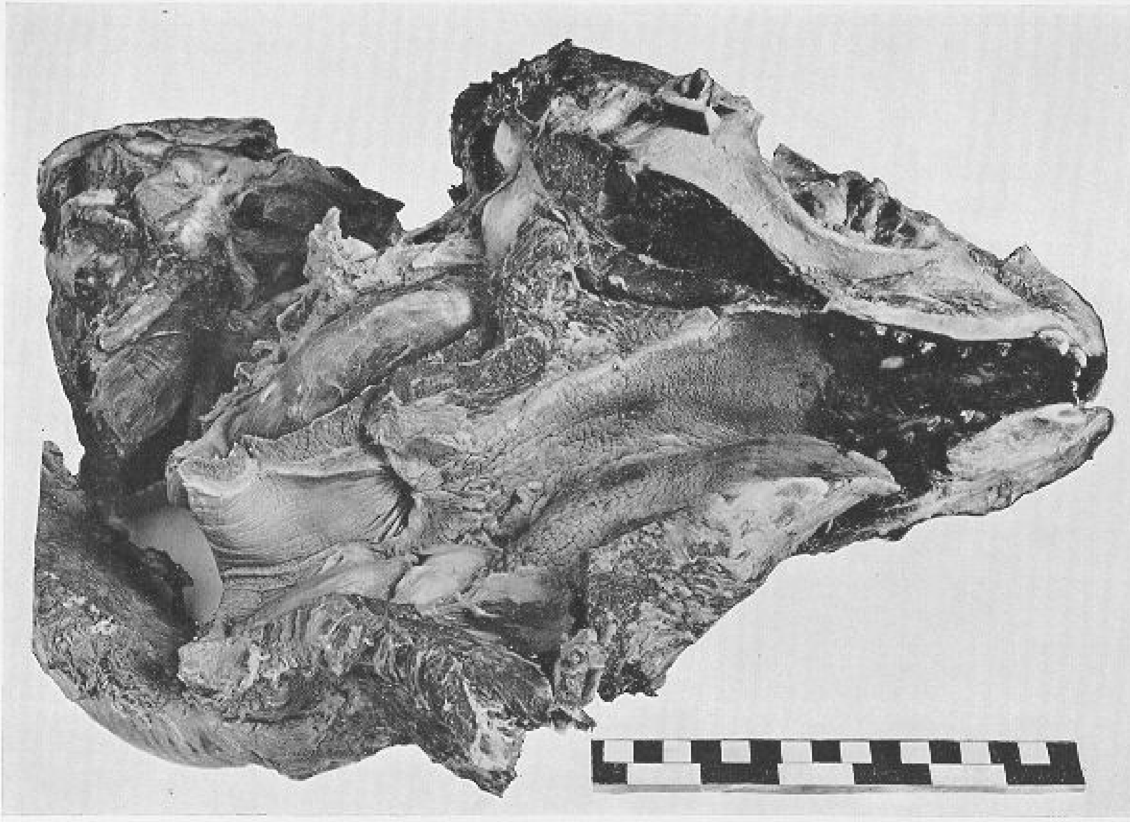


PLATE VII

a. The tongue and mouth cavity of *Ommatophoca* (female) showing the long soft palate. *b.* bulla; *c.* ceratohyal; *h.* hyoglossus; *ic.* inferior constrictor; *ip.* internal pterygoid; *lc.* longus capitis; *mc.* middle constrictor; *p.* palatopharyngeal; *sg.* styloglossus; *sh.* stylohyal; *sp.* stylopharyngeus.

b. The mouth cavity of *Phoca vitulina* showing the more usual length of the soft palate. (Photographs: BM(NH))



a

b

PLATE VIII

Dorsal view of the tongue and epiglottis of female *Ommatophoca*.
(Photograph: BM(NH))

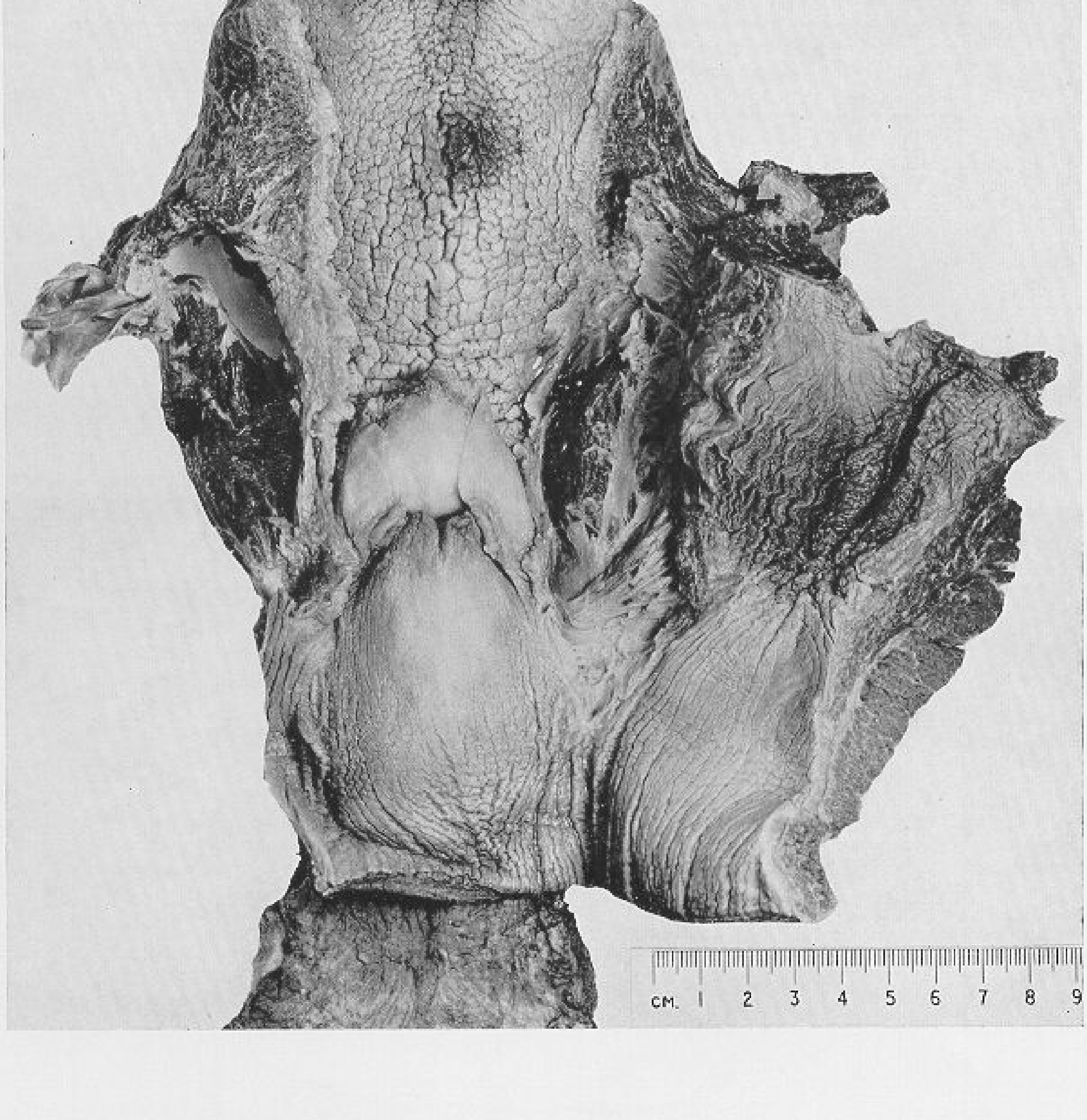
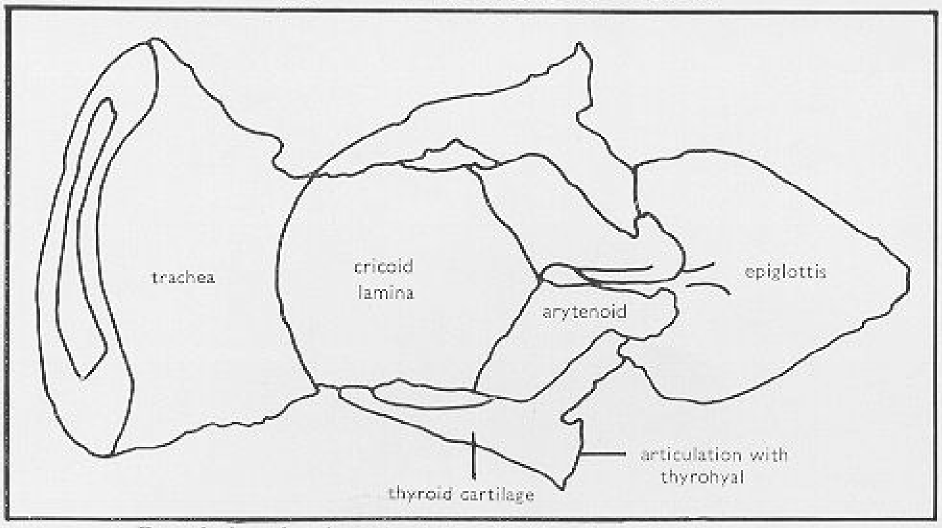
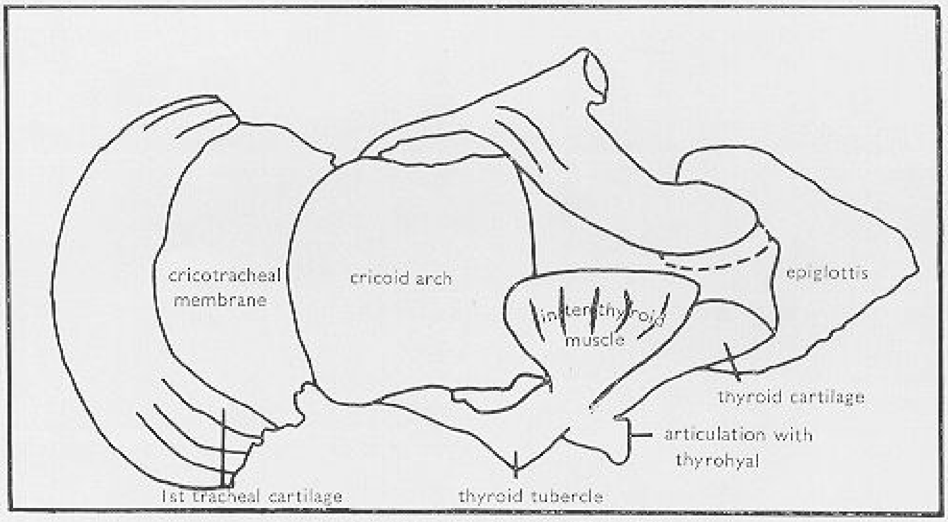

CM. 1 2 3 4 5 6 7 8 9

PLATE IX

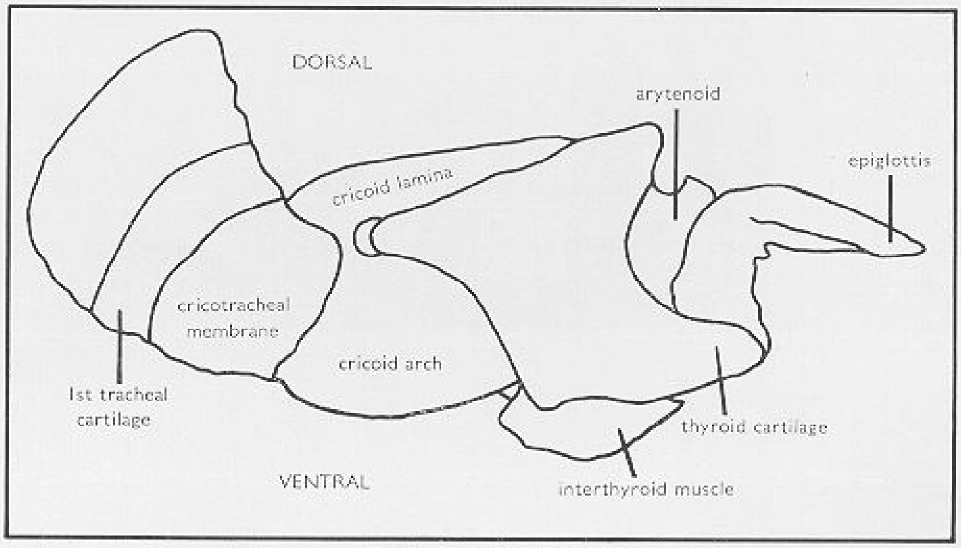
Laryngeal skeleton (Photographs: BM (NH))



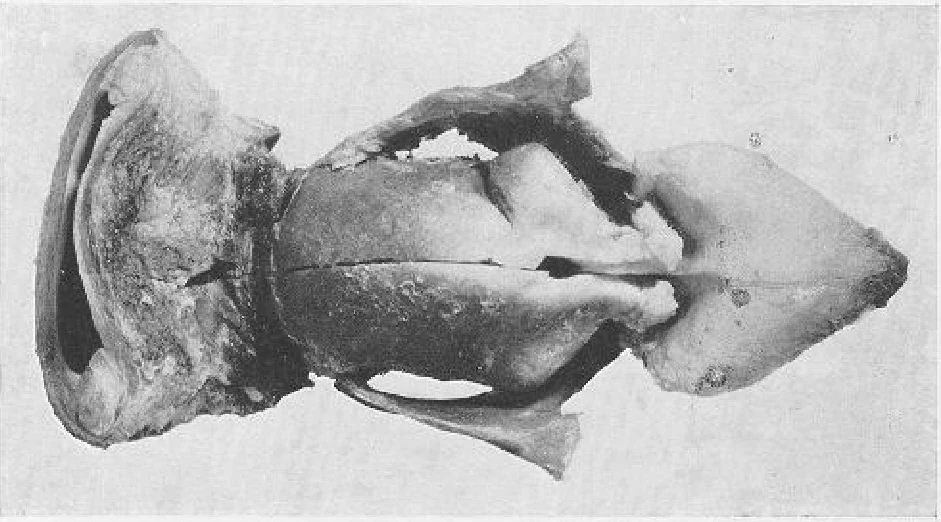
a. Dorsal view showing where the cricoid and trachea have been cut. Scale as in Plate IXc.



b. Ventral view. Scale as in Plate IXc.

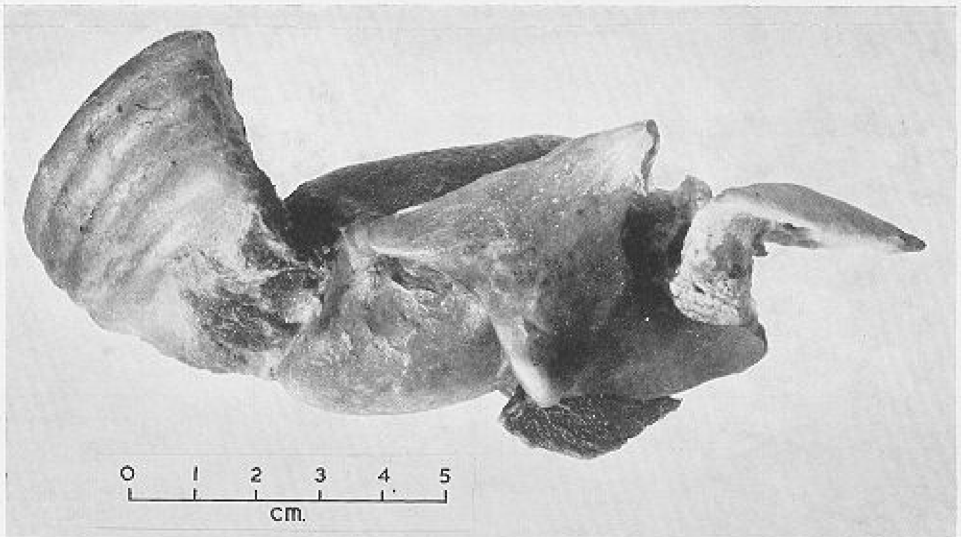


c. Lateral view (right side).



a

b

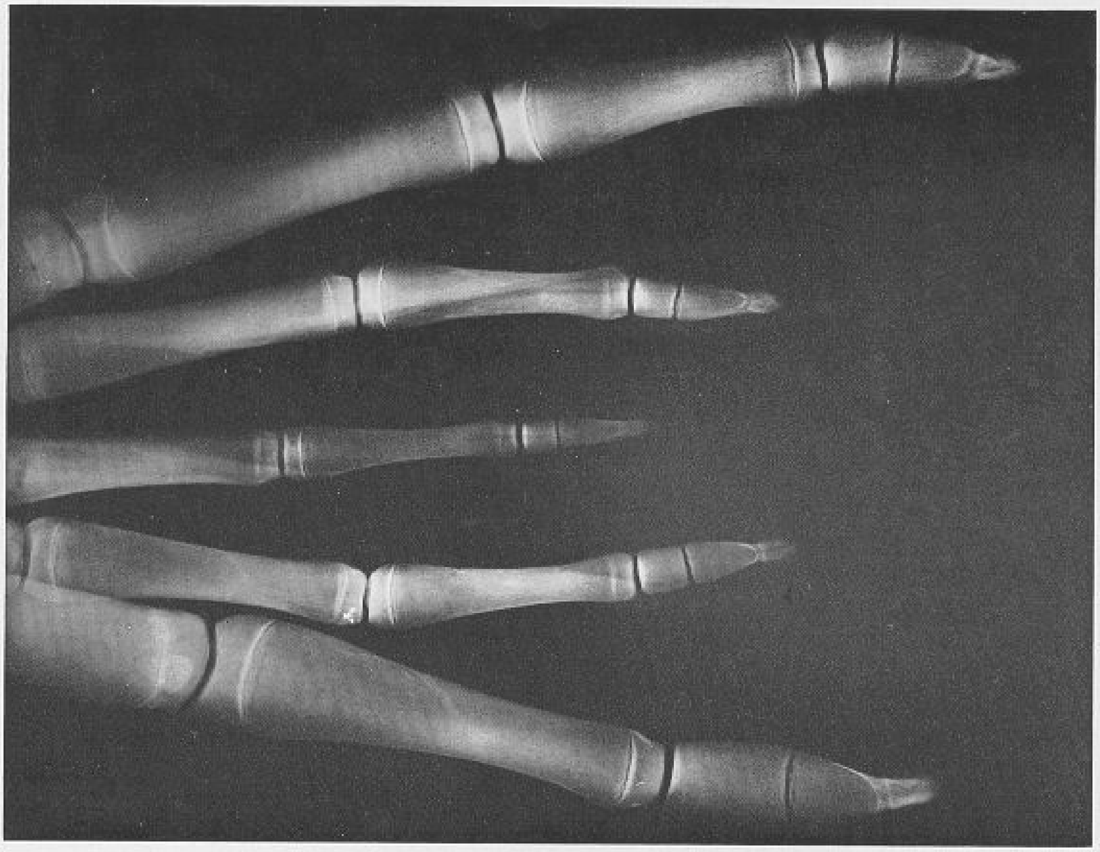


c

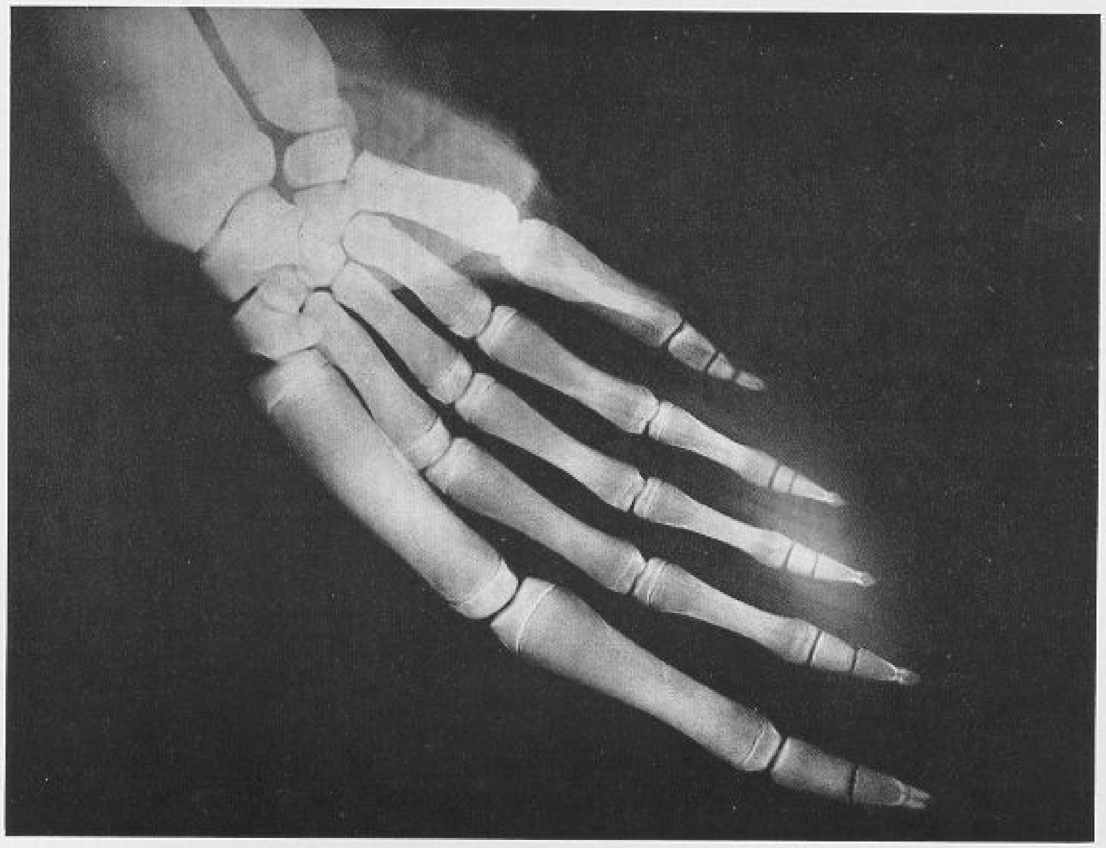
PLATE X

a. Radiograph of female *Ommatophoca* fore flipper.
(Photograph: BM(NH))

b. Radiograph of the distal tip of female *Ommatophoca* hind flipper.
(Photograph: BM(NH))



b



a