A CASE OF THE CACHALOT WITH PROTRUDED RUDIMENTARY HIND LIMBS

TEIZO OGAWA* AND TOSHIRO KAMIYA*

Needless to say, no protrusion of the hind limb is seen in all the Cetacea in their postnatal life. Only in the early embryonic stage they show a pair of protruded hind limbs, which but soon disappear (Guldberg, Kükenthal, Ogawa etc.). On the other hand, the existence of a pair of small pelvic bones is known as to nearly all of the Cetacea, lying far apart from the vertebral column on both sides of the genital opening. In the fin and blue whales and in the humpback the femur too is present near the pelvis, and in the right whale even the tibia exists. Of course these bones are deeply buried under the skin, causing no protuberance on the body surface. The circumstance is somewhat similar to the tail of the human being. The tail is well developed in the early embryonic stage of *Homo sapiens*, but disappears in the later stage, leaving as residue only the coccyx and related structures, all of which are concealed under the skin. Therefore, such whales as those having protruded hind limbs in the postnatal life must be an interesting object to study, about equally as the so-called tailed men.

In 1921 R. C. Andrews reported a remarkable case of the humpback whale with a pair of long protruded hind limbs. It was captured in July 1919 near Vancouver Island, British Columbia, Canada, by a ship operating from the whaling station at Kyuquot. The report tells, it was "a female humpback of the average length with elementary legs protruding from the body about 4 feet 2 inches, covered with blubber about one-half an inch thick". One of the legs had been cut off by the crew of the vessel and lost, but the other leg was photographed *in situ* at the whaling station.

The photograph and the skeletal remains, i.e. two bones and two heavy cartilages, were sent from F. Kermode, Director of the Provincial Museum, Victoria, B. C., to R. C. Andrews of the American Museum of Natural History, New York. And the latter author identified the bones as tibia and metatarsal, the cartilages as femur and tarsus, and published his findings on the skeletal remains together with the photograph. He concluded that "the protrusions actually do represent vestigial hind limbs and show a remarkable reversion to the primitive quadripedal condition". With sufficient reason he rejected the idea of a teratological

* Department of Anatomy, Medical Faculty, University of Tokyo.

case of no reversionary significance.

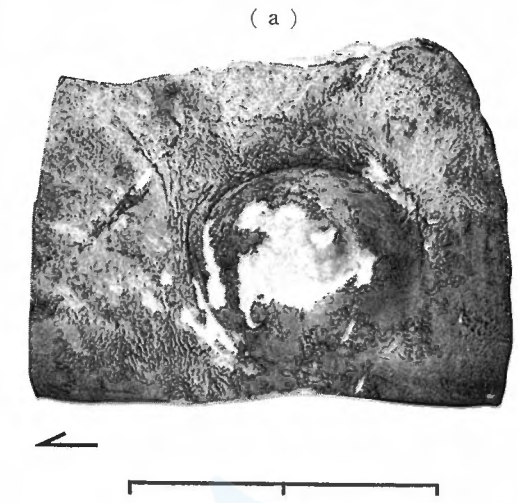
Recently another individual belonging however to the Odontoceti and possessing likewise a pair of protruded hind limbs was encountered in Japan. It was a *Physeter catodon* captured at 3.30 p.m. of November 8th, 1956, by a boat named Daisantoshi-maru of the Nihonkinkai Whaling Company, about 100 miles ES off Kinkwazan (N 37°12′, E 143°35′). According to the report presented from the whaling station, it was a female measuring 10.6 m in length. The protuberances were present on both sides of the genital opening; but to our regret no photograph was taken on the limbs *in situ*. When the body was cut at the Ayukawa whaling station, two skin areas (each area of about 750 qcm) with the protrusion placed near the center were excised with underlying blubber and preserved in formalin at the Whales Museum of Ayukawa.

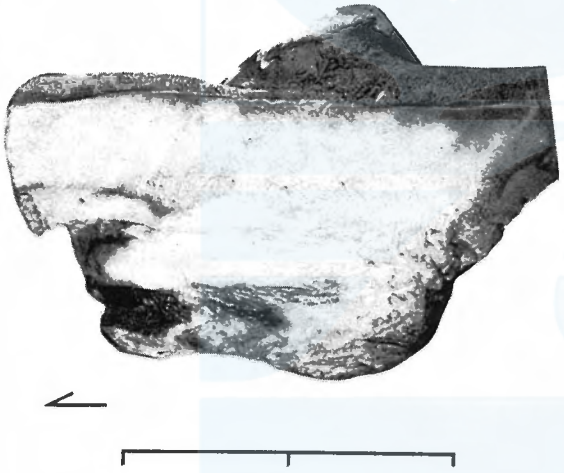
Shortly after the event, Dr. H. Omura, Director of the Whales Research Institute of Tokyo, visited the museum and noticed the presence of these valuable specimens. They were delivered soon to us for anatomical researches. We wish to say here sincere thanks to Dr. Omura and to the personnel of Ayukawa for their courtesies in allowing us to have the opportunity of studying this precious material.

OBSERVATIONS

The protrusions are nearly of the same size and similar form on both sides (Figs. 1 and 2). They are elevated like a dome, or conical with the tip rounded. On the left side it protrudes a little more sharply than on the right. The summit of the elevation, appearing rather like a plateau, lies not in the middle, but remarkably behind; in other words, the axis of the elevation is directed caudad and ventrad. The anterior slope is longer and wider, while the posterior one is shorter and more rapid. The height measures 5.35 cm on the right side, 6.56 cm on the left. The limbs are therefore in the present case uncomparably shorter than in the Andrews' case. The circumference at the base is on the right side 49.5 cm (anteroposterior diameter 16.6 cm, transverse one 14.0 cm), on the left side the circumference at the base 43.5 cm, (15.0 cm, 13.0 cm). Seeing as a whole, the left limb is relatively more slender; the right one is a little thicker and shorter. The summits show baldness in some extents, where the epidermal covering is lacking and white smooth surface of the corium is exposed externally.

After consulting the Röntgen photographs we searched into the interior of the left limb. The pelvic bone measuring 19.5 cm in length was found there, looking like a hatchet in form, with the edge directed laterad. It seems to run grossly in the anteroposterior direction, but its





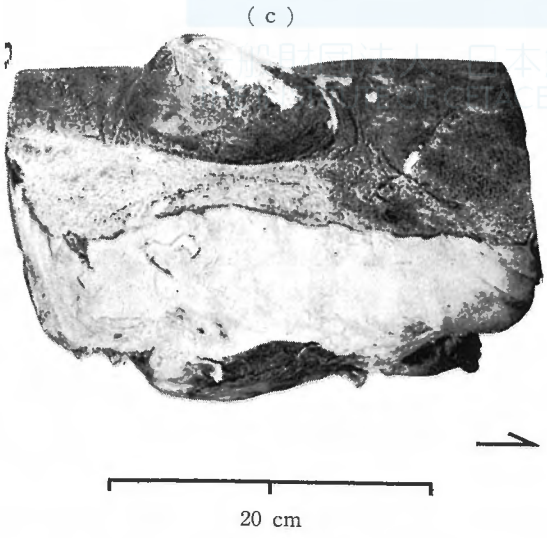
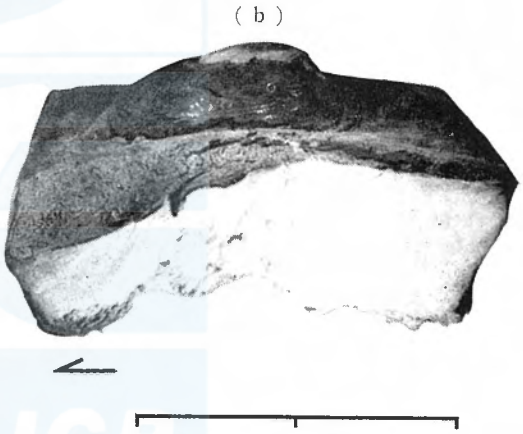


Fig. 1. The left hind limb. (the arrow denotes the anterior direction)



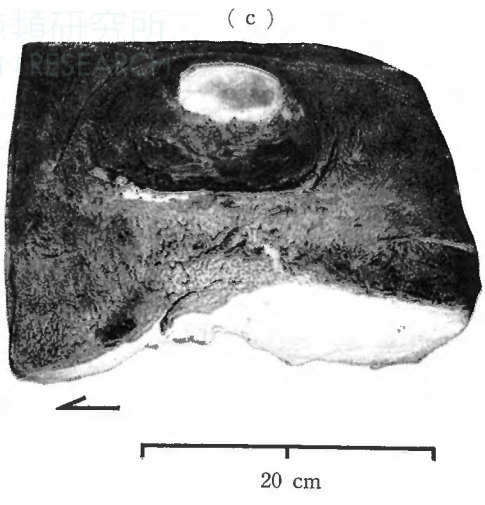


Fig. 2. The right hind limb. (the arrow denotes the anterior direction)

anterior part lies probably more mediad than the posterior. It is narrower in the anterior half, and becomes broader transversely in the posterior half which is still cartilaginous in a large extent (Fig. 3).

Laterad in the neighbourhood of the pelvis, nearly at the middle part of this bone, the femur covered with cartilage is present taking the form of a small ball with the diameter ca. 3 cm (its osseous part 2.2 cm measured on the Röntgen picture). It is easily movable against the pelvis, but no joint is formed between them; their firm connection is attained by the connective tissue and especially by muscles. Concerning the latter, two strong muscular masses are attached to the femur, one coming from anterior and the other from posterior. The anterior mass (M_1 and M_2 in Figs. 3, 4, 5), which corresponds in our opinion seemingly to adductors, takes origin mostly from the anterior half of the pelvis (M_2), the rest comes from somewhere more anterior portion (M_1), possibly from muscles of the abdominal wall, while the posterior mass (M_3 and M_4 in Figs. 3, 4) starts for the small part from the posterior half of the pelvis (M_3), but for the greater part from somewhere more posterior portion (M_4), probably from the caudal musculature. The posterior mass corresponds in our opinion to the ischiofemoral muscles and to such muscles as m. glutaeus maximus.

A pretty wide space triangular in shape (S in Figs. 3, 4) remains between pelvis and femur. This space, bordered fore and behind by the muscular masses mentioned above, is filled with areolar and adipose tissues, while large nerves and vessels pass through there to be distributed further to the hind limb.

Lateroventrally 4.8 cm distant from the femur a mostly cartilaginous stick of the length 13 cm is present. It is only partially ossified. The distal half and the proximal one-fourth are cartilaginous, while the remaining part (the second one-fourth from the proximal end) is ossified and this osseous part (3.5 cm long, 1.8 cm wide) is thicker enlarged chiefly on the anterior side, in comparison with the other cartilaginous portions.

It is difficult to determine whether this stick be corresponding either to tibia, fibula, or both of them fused together, or rather to an isolated distal portion of femur. But we take it provisionally for tibia in view of two slender muscles coming from the femur, and inserting to the anterior surface of the bony part of this stick.

Between femur and tibia no joint like the knee exists, as both bones are not in contact but far (4.8 cm) apart from each other. The distal end of the stick lies in the central part of the protruded hind limb, only 2 cm interior from the surface of the summit. As the thickness

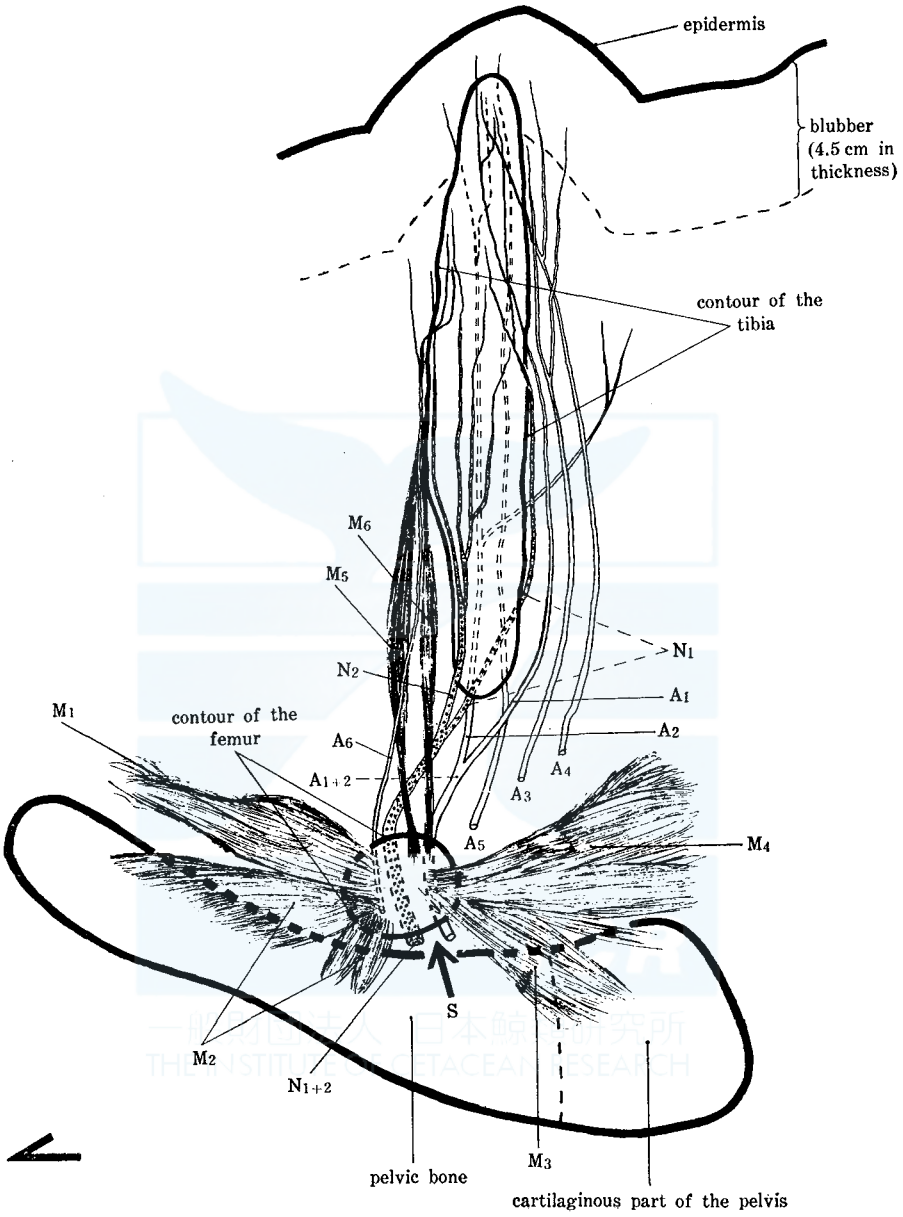


Fig. 3. Schema showing the interior of the left hind limb. (the arrow denotes the anterior direction)

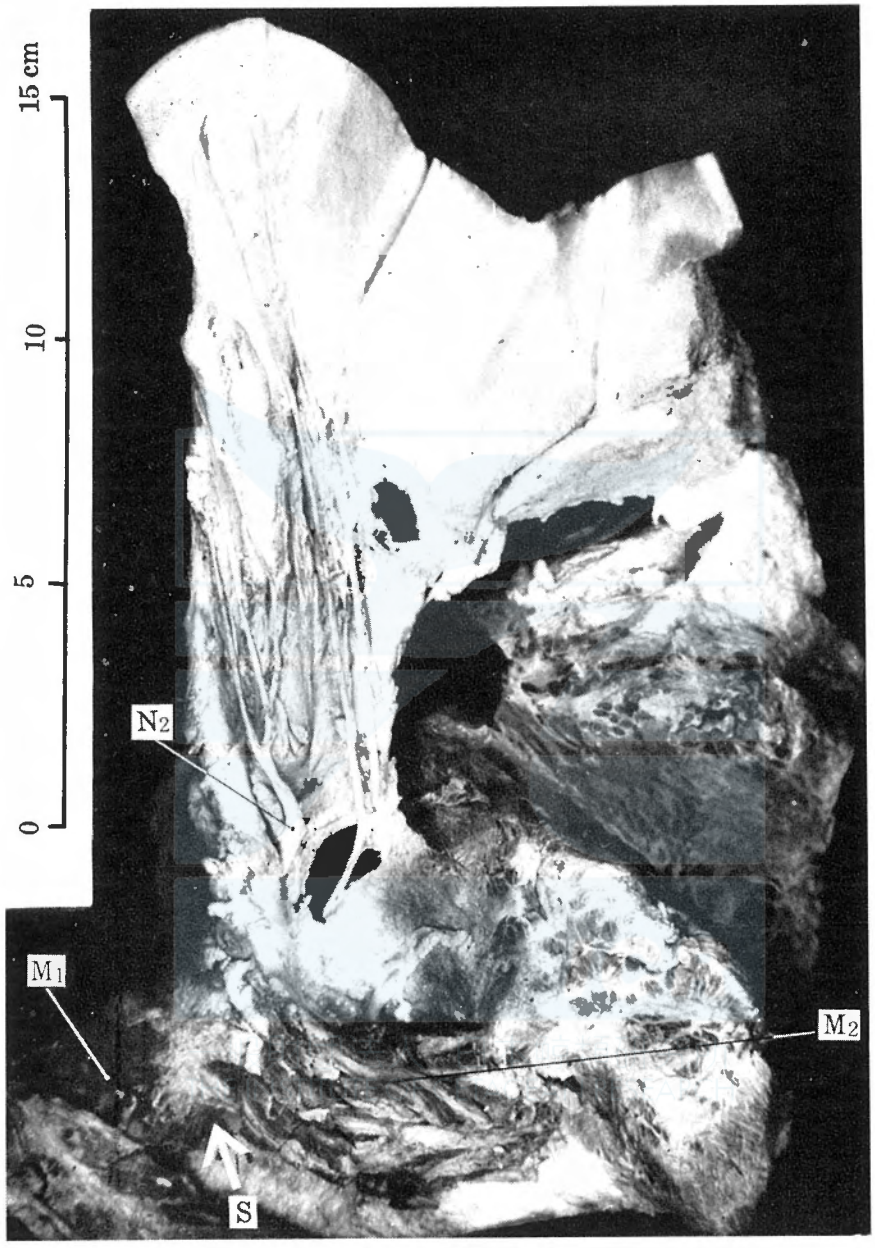


Fig. 4. Interior of the left hind limb, seen from caudal and ventral.

Fig. 5. Interior of the left hind limb, seen from rostral and a little ventral.

of the dermis in the vicinity of the protuberance measures 4.5 cm, the cartilaginous distal extremity is pierced into the skin, so to speak, in a pit on the inner surface of the dermis (Fig. 3).

Two weak muscles (M_5 and M_6 in Fig. 3) are attached to the osseous tibia by intercalation of tendons. For the time being we take these muscles for the rudimentary mm. vasti. A part of the inserting tendons becomes fleshy again and forms a thin muscular plate firmly attached to the anterior surface of tibia (* in Fig. 5). Besides an amount of whitish muscular fibers can be seen, coming somewhere from more superficial part to end also at the bony portion of tibia. We are induced to explain this part of tibia as the tuberositas tibiae. Though these muscles inserting to tibia seem altogether to be homologous with m. quadriceps femoris, no bone is found, which may be identified with the patella.

Our attention was further given to the richneses of nerves and arteries pertaining to the limb. All of them run nearly parallel to the tibia in the proximal-distal direction, but their courses are slightly spiral; especially nerves show more remarkably the spiral course than arteries. At the proximal extremity of the stick two large nerve trunks are seen, one on the anterior side (N_1 in Figs. 3, 5), the other on the posterior side (N_2 in Figs. 3, 4). Both trunks despatch many branches and hence become thinner, but the peripheral continuation of N_1 comes distally to the posterior side of the stick, while the continuation of N_2 attains distally the anterior side of the stick. The "spiral course" is meant by this gradual change of their locations in relation to the tibia. Very probably the tibia rotated around its longitudinal axis during the development and the nerves followed the rotation consistently.

As to large arteries we have counted six of them (A_1, A_2, A_3, A_4, A_5, A_6 in Fig. 3) at the proximal end of the tibia. It is noteworthy, that most of them reach the interior of the protruded hind limb, though they become thinner after issuing branches on the way. Three of the six (A_2, A_5, A_6) run before the tibia, while the remaining three (A_1, A_3, A_4) go behind it, and some of the six arteries show slight tendency of the spiral course. We felt at first queer, why we do not meet with veins in this material, but ascertained afterwards under microscope, that each artery is accompanied by thin-walled venous channels attached intimately to its wall and that these comitant small veins can not easily be recognized by the naked eye.

All of the nerves destined to the hind limb are continuous from a thick trunk (N_{1+2}) passing through the triangular space between pelvis and femur mentioned above (S). Nearly all of the arteries come also from the same space, through only as to one artery (A_4) the same fact was not proven, as it had been destroyed on the way. Nerves and

arteries run at first ventral to the pelvis, then dorsal to the femur, to reach further the tibial region.

The skin covering the hind limb was examined histologically and compared with the skin outside but near the elevation. The stratum cor-

Fig. 6. Cross-section of an artery (A_1) with three comitant venous channels. One of them (upper left) shows venous valve.

neum was disjuncted on both localities, certainly a post mortem occurrence. We noticed that at the height of the limb the papillae made of the corium are much slender and grow more densely than in the neighbouring usual skins.

COMMENTS

Compared with the humpback reported by Andrews (1921), the present case is different not only in the kind of the whale, but very much also in the lowness of the protruded hind limbs. The height is in our *Physeter* only 5–6 cm, while in the Andrews' case it was said so long as 4 feet 2 inches, when fresh. It is to be noted, that our case resembles in a much higher degree the bud-like state of the hind limbs in the early Cetacean embryos.

Existence of the hind-limb elevation was at first reported in a 7 mm embryo of *Phocaena communis* by Guldberg of Norway in 1894. Kükenthal, the famous German zoologist, was very much interested in this problem and published later his findings on small embryos of *Megaptera*

nodosa and *Phocaenoides dalli* (1914). According to him a 32 mm long embryo of *Megaptera* showed very clearly the hind-limb elevation on both sides of the genital tubercle, and it measured 1.2 mm in height and 0.9 mm in width at the base. It was conical, but rounded at the tip, papilla-like, and flat laterally and caudally directed.

In a recent paper of Ogawa (1953) the hind-limb protrusion was mentioned in 14 mm, 20 mm, 24 mm embryos of *Prodelphinus caeruleoalbus* and in a 20 mm embryo of *Megaptera nodosa*. The protrusion was the most conspicuous in the 14 mm *Prodelphinus*. It was rather conical and pointed, the apex being directed caudad and laterad. By adding more materials to observation Ogawa said for the first time the simultaneousness of the disappearance of the hind-limb elevation with the first appearance of the caudal flukes in the Cetacean embryos.

Unquestionably the present case happened to occur by abnormal retention of this early embryonic state, due to some unknown factor, by hindrance to the normal development. Not only the location, but also the form, i.e. conical with the rounded tip directed caudally, seems to agree well between the early Cetacean embryos and the present case of *Physeter*.

In the Andrew's *Megaptera* the hind-limb protrusions were very long, and contained 14.5 inches long tibia and more than 6 inches long metatarsal, moreover two heavy cartilages representing femur and tarsus. This humpback can not be explained merely by the retention of the normal development, but shows more positive tendency of generating the hind limbs. The atavism of the whale back to the quadripedal condition was seen there more pronounced.

But the difference between the two cases is never essential, but rather a problem of quantity. Both mean equally a reversion to the quadripedal ancestors. There can perhaps be no other explanation. In our case of the short hind limbs the partly ossified femur and the 13 cm long, mostly cartilaginous, for the smaller part osseous tibia was found. Guldberg (1899) and Hosokawa (1955) saw histologically neither cartilage nor bone in the hind-limb elevation of the Cetacean embryos, only a mass of mesenchyme cells. In the hind limb of our case further differentiation of the tissues has certainly taken place; it retained the early embryonic state only in location and form, but not in the histological structure.

Upon dissecting the bud-like hind limb we were rather surprised by the relative abundance of arteries and nerves, and on the contrary by the apparent paucity of veins. Microscopic studies revealed however the rich existence of thin-walled venous channels in the very vicinity of the arteries. This relation reminds us of the recent paper of Scho-

lander and Schevill (1955), which deals with the blood-vessels lying deeply in the fins and flukes of *Lagenorhynchus acutus* and *Tursiops truncatus*. According to them, all major arteries are located centrally within a trabeculate venous channel, and this results in two concentric conduits with the warm one inside, which they explained as a heat-conserving counter-current system. Anyway we are interested in seeing the similar vascular relations in the rudimentary hind limb.

The richness of the nerves led us to recall the experiments of Detwiler (1936) and others, who after grafting extremities in the larvae of *Amblystoma* to unusual regions saw hyperplastic growth of the corresponding peripheral neurons. The unusual outgrowth seems to bring forth the adequate development of peripheral nerves even in these warm-blooded, pelagic mammals.

SUMMARY

In a nearly adult female Cachalot captured in November of 1956, off Kinkwazan in Japan, a pair of bud-like vestigial hind limbs were present. The height of the protuberance was 5.35 cm on the right side, 6.56 cm on the left side.

Upon examining the interior of the left limb three partially cartilaginous bones were found. They correspond to pelvis, femur, and possibly to tibia, but no joints exist between them. Pretty strong muscles connect between pelvis and femur, while two weak muscles are extended between femur and tibia. The tibia is a 13 cm long for the greater part cartilaginous, and only partly ossified stick-like body with its distal end inserted into the skin of the hind-limb protuberance.

A number of arteries and nerves run parallel to this tibia distalward and especially the nerves show the tendency of spiral course around the stick. The veins are not easily visible by the naked eye, but they are found attached intimately to the wall of arteries.

This case can be understood by assuming abnormal retention of the early embryonic state, and show very probably an atavism back to the quadripedal condition of the whales' remote ancestors. It can never be a malformation of no phylogenetic significance.

LITERATURE

ANDREWS, R. C. (1921). A remarkable case of external hind limbs in a Humpback whale. *Amer. Mus. Novitates*, no. 9: 1–6.

DETWILER, S. R. (1936). *Neuroembryology*. New York.

GULDBERG, G. (1894). Ueber temporäre äussere Hinterflossen bei Delphin-Embryonen. Verhandl. d. anat. Gesell. auf der 8. Versamml. in Strassburg am 13–16. Mai, 1894. *Anat. Anz.* Bd. 9, Ergänz. 92–95.

GULDBERG, G. (1899). Neuere Untersuchungen über die Rudimente von Hinterflossen und die Milchdrüsenanlage bei jungen Delphinembryonen. *Internat. Monats. Anat. Physiol.*, Bd. 16: 301–321.

GULDBERG, G. & Nansen, F. (1894). *On the Development and Structure of the Whale. Part 1: On the Development of the Dolphin.* Bergen.

HOSOKAWA, H. (1951). On the pelvic cartilages of the balaenoptera-foetuses, with remarks on the specifical and sexual difference. *Sci. Rep. Whales Res. Inst.*, no. 5: 5-15.

——— (1955). Cross-sections of a 12-mm. dolphin embryo. *Sci. Rep. Whales Res. Inst.*, no. 10: 1–68.

KÜKENTHAL, W. (1895). Ueber Rudimente von Hinterflossen bei Embryonen von Walen. *Anat. Anz.*, Bd. 10: 534–537.

——— (1914). Untersuchungen an Walen. Zweiter Teil. *Jenaische Z. Naturwiss.*, Bd. 51, S. 1–122.

OGAWA, T. (1953). On the presence and disappearance of the hind limb in the cetacean embryos. *Sci. Rep. Whales Res. Inst.*, no. 8: 127–132.

SCHOLANDER, D. F. & Schevill, W. E. (1955). Counter-current vascular heat exchange in the fins of whales. *J. Applied Physiol.*, 8 (3): 279–282.

STRUTHERS, J. (1872). On some points in the anatomy of a great Fin-whale (*Balaenoptera musculus*). *J. Anat. Physiol.*, 6: 107–125.

——— (1881). On the bones, articulations and muscles of the rudimentary hind-limb of the Greenland Right-whale (*Balaena mysticetus*). *J. Anat. Physiol.*, 15: 141–176., 301–321.

——— (1888). On some points in the anatomy of a *Megaptera longimana*. Part 2. The limbs. *J. Anat. Physiol.*, 22: 240–282.

——— (1893). On the rudimentary hind-limbs of a great Fin-whale (*Balaenoptera musculus*) in comparison with those of the Humpback whale and the Greenland Right whale. *J. Anat. Physiol.*, 27: 291–335.