

Morphology and histology of the laryngeal sac of toothed whales

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Abstract

The laryngeal sac in the larynx of toothed whales differs considerably from the other sinuses in the base of the skull. There are widely divergent accounts of the function of this organ in the literature so a new study has been undertaken.

These new findings note that the laryngeal sac is morphologically and histologically comparable with the lungs of young mammals or turtles. The laryngeal sac can therefore be regarded as functionally a respiratory organ. Histological studies may provide a complete answer to this question. For this, however, live material would be required, which is not available to the author. Anyone who is able to come by such material should either continue these studies or immediately fix the material and send it to the author.

Introduction

Ventrally in the larynx of toothed whales, immediately in front of the trachea, there is a sac-like organ (*Saccus laryngalis*) the function of which has never been satisfactorily explained. Hosokawa (1950) collated previous knowledge on the function of this organ, and proposed for discussion three hypotheses, which have been used as the starting point for new research.

Material

The laryngeal region of the following species of toothed whales were available for this study: *Lagenorhynchus albirostris*, *Tursiops truncatus*, *Delphinus delphis* and *Phocoena phocoena*.

The head of a *Phocoena* was cut into discs 5-10 mm thick, illuminated and fixed. The larynxes of the other whales were completely coated in paraffin wax, or cut into histologic sections. All the prepared material is available for further study.

Findings

In all the toothed whales studied, the laryngeal organ, hitherto known in the literature as the laryngeal sac, is situated ventrally in the caudal larynx

(Fig. 1, 2). The tissue which forms the sac consists of smooth muscle, and the epithelium which covers it is similar to that of the larynx. Ventrally and laterally, the organ is surrounded by a muscle (*Musculus thyroarytaenoideus*). The direction of contraction of which makes it possible for the organ to be drained. The organ and muscle are encased ventrally and laterally by the laryngeal cartilage (*Cart. cricoidea*), and are free dorsally (Fig. 4).

The interior of the organ is divided sagittally by an elastic cartilaginous septum, which branches laterally. This branching gives rise to ventricles in which are sacs. They are covered medially with folds, reticular connective tissue and a pulmonary epithelium (Figs. 2, 3). At the tips of the folds are string-like ciliated cells (Figs 4, 5). The tissue that lines the sacs is interspersed with many blood vessels and simply terminating strings of nerves. Only occasional mucilaginous cells are found.

From the sacs lead channels, which join up and discharge into the laryngeal tube dorsally of the caudal epiglottis. The larynx is morphologically similar to a reptile lung (Fig. 6). The histologic sections show a tissue from such as is found in the lungs of young mammals (Fig. 5).

Discussion

The oldest known description of a laryngeal sac is that by Hunter (1787). He discovered an air sac ventral of the larynx in a baleen whale (*Balaenoptera rostrata*). Dubois (1886) found a similar sac in the larynx of toothed whales. As the laryngeal sac of baleen whales had been described as an air sac, it was natural to regard the laryngeal sac in the larynx of a toothed whale as an air sac likewise.

Hosokawa (1950) in his study of laryngeal sacs began to have doubts as he found considerable differences between the laryngeal sacs of baleen and those of toothed whales. His histological studies of the 'inner laryngeal sac with the structure of a brain' produced results which did not, at first, permit any clear assertion as to the function of the organ. He found tissue forms comparable with those of the pharynx, larynx and lungs. His thoughts on the function of the laryngeal sac he summed up in three

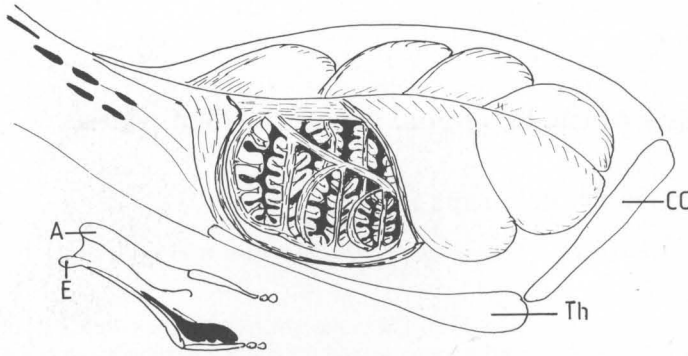


Abb. 1

Abb. 2

Abbreviations in the figures

A	Arytenoid cartilage
CC	Cricoid cartilage
Ce	Elastic cartilage
E	Epiglottic cartilage
F	Ciliated epithelium
L	Larynx
LE	Bronchial epithelium
RB	Reticular connective tissue
T	Trachea
Th	Thyroid cartilage

Figure 1. Schematic longitudinal section through the larynx of a toothed whale (*Phocoena phocoena*) with laryngeal organ.

Figure 2. The laryngeal organ.



Figure 3. Cross section of laryngeal organ of *Phocoena*. The lighter cartilaginous tissue is clearly distinguishable.

hypotheses, which are given here in abbreviated form.

1. The organ prevents foreign bodies from penetrating into the respiratory canal.
2. Any oxygen in the air breathed in, which has not been taken up by the lungs is absorbed here.
3. By ventilation the sac assists vocalization.

The third hypothesis was later taken up by Purves & Pilleri (1983). They proceed on the assumption that the laryngeal sac is a reservoir of air with the help of which the whale produces sounds.

In the case of the laryngeal sacs of baleen whales, situated outside the larynx, it could, according to Negus (1982), be a question of evolutionary derivatives of the larynx, such as are found in many mammals (Negus, 1962). These air sacs of baleen whales are very large and could take up

correspondingly large quantities of air and these could aid in vocalization.

The laryngeal sacs of toothed whales, on the other hand, are very small and because of their situation within the larynx they are not capable of much expansion. Even in large toothed whales, the volume of the internal laryngeal sacs amounts only to a few cubic centimetres. A large and rapid change of volume such as would be required for the production of sound would be obstructed by the internal cartilaginous structure. An expansion of the laryngeal sac, as described by Purves & Pilleri (1983) could not be achieved experimentally. It is, therefore, unlikely that the laryngeal sacs assist vocalization.

A multi-layered connifed flattened epithelium, characteristic of the pharynx and oesophagus, was not found despite an intensive search. Nor were any

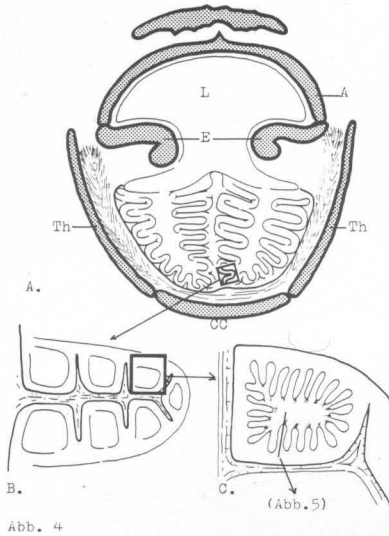


Abb. 4

Figure 4. Laryngeal organ of *Phocoena* in cross section: A = enlarged two-fold; B = enlarged eight-fold; C = vacuole with folded ciliated tissue, enlarged 16 times.

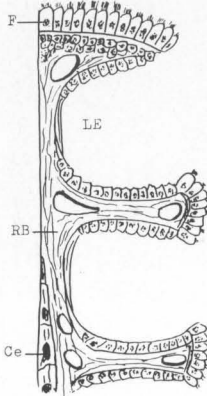


Abb. 5

Figure 5. Horizontal section through a fold. See Figure 4C.

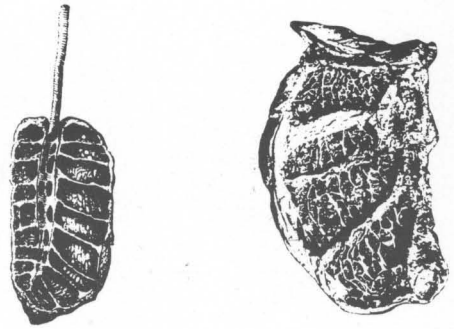


Abb. 6 Reptilienlungen

Marcus, Handbuch der vergl. Anatomie der Wirbeltiere

Figure 6. The lungs of a turtle from Marcus (1937) as a comparison.

mucous or other exocrine glands present, such as would be necessary for flushing out foreign bodies. The number of mucous glands is very small, which distinguishes the larynx clearly from the caudally adjoining air passage glands (*Glandula laryngalis*). So Hosokawa's (1950) first hypothesis is also incorrect.

On the other hand, there is a lot in favour of the second hypothesis, that the laryngeal sac is a respiratory organ. Morphologically, it can be compared with a primitive lung, like, for example, that of the turtle. The tissue that forms the sac is similar to that of the larynx. The epithelium that lines the sacs is comparable to that of young mammals.

The design of the organ also permits inferences to be drawn regarding its function. During dives, with the air passages closed, sounds are produced by the ventilation of air between the lungs and the air sacs. At the same time, air which still contains oxygen can be directed onto the laryngeal organ and after it has given up its oxygen forced out again by the muscle.

Final proof of this can be obtained only from histochemical examination for which very fresh material is necessary, and this is not available to the author.