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## A ciliated epithelium covering the inner surface of the glove finger in *Balaenoptera physalus* Linnaeus, 1758

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### Abstract

Studied the glove finger in *B. physalus*, which is protruding from the bulla tympani into the external auditory meatus. Histological examination revealed that the inner surface of this structure is covered by an epithelium which is composed of ciliated cells alternating with secretory cells. The presence of this epithelium allowed some conclusions about the origin of the glove finger in Balaenopteridae.

### Introduction

The epithelium covering the meatal surface of the glove finger in *B. physalus* is described by ICHIHARA (1959) while PURVES (1955) studied the histology of the earplug, formed on and for the main part by this epithelium. ICHIHARA also gives a short description of the glove finger.

The glove finger is a hollow thick-walled and dome-shaped protrusion, penetrating over a relatively short distance from the bulla tympani into the external auditory meatus (fig. 1). It is composed of a number of layers of connective tissue, in which the fibres in each layer are running in a different direction. The meatal surface of this thick membrane is covered by an epithelium, which is of epidermal origin and is not or only slightly pigmented. During the embryonal development in the Balaenopteridae, considerable changes occur in the shape of the tympanic membrane. FRASER and PURVES (1960) mention the fact that in a 6 inch foetus of the Humpback whale (*Megaptera novaeangliae*) the tympanic membrane is still in a horizontal position. HANKE (1914) found that in the foetus of the Balaenopteridae the tympanic membrane at first had the same form as in other mammals. In later stages of the development, however, at least a part of the membrane protrudes into the external auditory meatus.

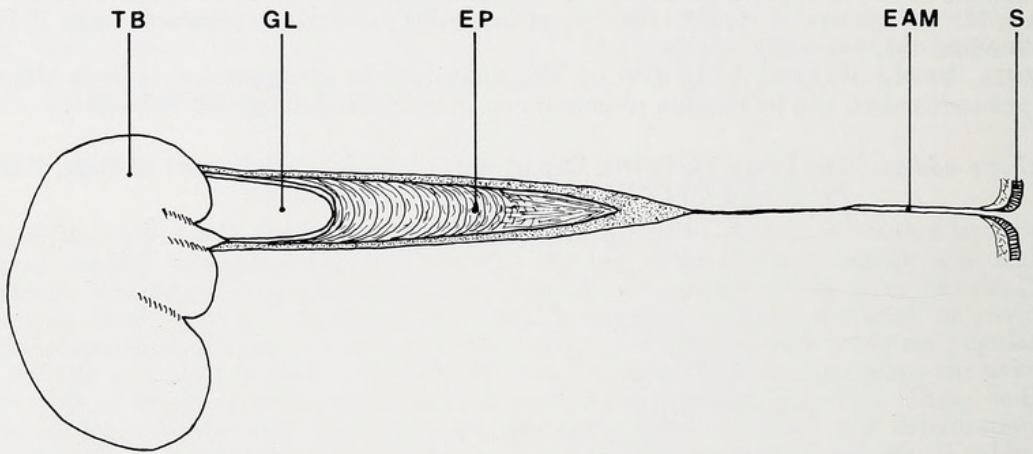


Fig. 1. Scheme showing the position of the glove finger in *B. physalus* in relation to the bulla tympani and auditory meatus. TB = tympanic bulla; GL = glove finger; EP = ear plug; EAM = external auditory meatus; S = skin

VAN KAMPEN (1905) is of the opinion that the cavity of the glove finger is a secondary part of the tympanic cavity, while BEAUREGARD (1894) homologizes the lumen of the glove finger with one of the accessory air sacs. FRASER and PURVES (1954, 1960) disagree with the opinion that the glove finger is "the" tympanic membrane. In their view the homologue of the tympanic membrane is the triangular ligament inserted into the manubrium of the malleus. They consider the glove finger to be a derivative of the pars flaccida of the tympanic membrane (FRASER and PURVES 1960), so the tympanic membrane in the Balaenopteridae should be composed of a fibrous ligament and the glove finger. In the literature the descriptions of the tympanic membrane are mainly devoted to man. Only from a few other mammals short descriptions exist. A ciliated epithelium is only found on the walls of the tympanic cavity and also in the immediate vicinity of the annulus tympanicus. As far as could be ascertained with respect to the middle ear of the Cetacea, no descriptions exist of a ciliated epithelium covering the inner side of the glove finger.

### Material

From a number of female Fin whales the external auditory meatus was excised for collecting the earplugs. The meatus was cut from the bulla tympani, immediately at this bone and therefore at the basis of the glove finger. The whole meatus was released from the skull

and preserved in formalin 5%. This fluid was renewed several times and the material was stored for about eight months. After removal of the earplug from the meatus and from the glove finger, blocks of tissue were cut from different parts of the glove finger, going from the apex to its sides, in the plane of its greatest width. After dehydration and embedding in parafin, microscopic sections 5  $\mu\text{m}$  thick were made in the conventional way. The sections were stained with haemalum eosin, the Crossmon technique, iron haematoxylin Haidenhain, and Gomöri silver staining. The examination of the sections was done with a normal light microscope.

### Results

In a section of the glove finger of the Fin whale, parallel to the plane of its greatest width, the following components are present:

- a. Epithelium covering the meatal surface. This epithelium which is of epidermal origin, sometimes forms papillae of various sizes (fig. 2). These papillae are not present in the material of all animals examined. However, when present they are always found at the apex of the glove finger. The epithelium is composed of a stratum basale, a stratum spinosum and an interrupted stratum, formed by large vacuole-like cells which contain large granulae. This latter layer turns into the layered mass forming the earplug.

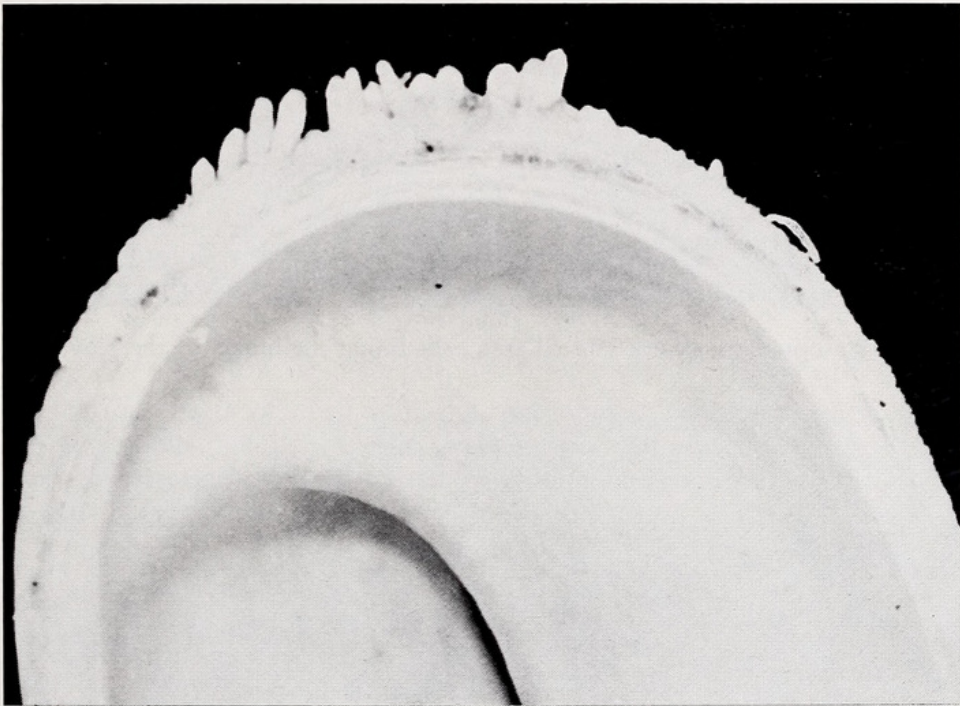
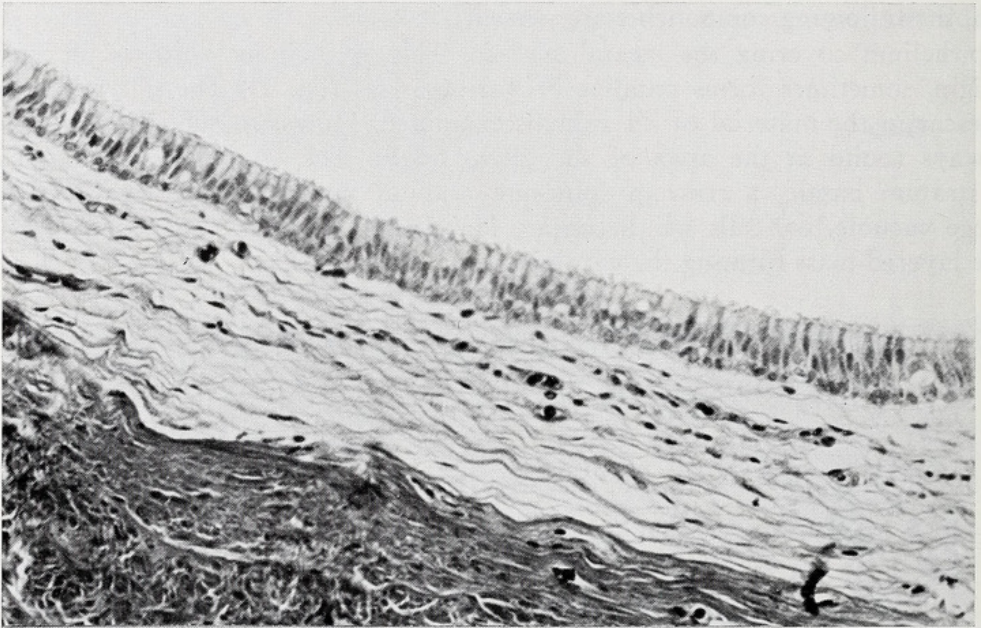


Fig. 2. Apex of the glove finger with papillae

- b. Underneath the stratum basale of the epithelium is a thin layer of fine loose fibrils forming the argentophylic network. In this layer numerous capillaries are present.
- c. The central part of the wall forming the glove finger, consists of a thick mass of collagen fibrils. It consists of three layers of coarse fibrils. The first layer has its fibrils mainly running in the plane of the section and parallel to the outer surface of the glove finger. In the second layer, which makes up the main part of the total thickness of the glove finger, the fibrils run in a direction more or less perpendicular to the direction of the fibres in the first layer. Here also a number of bundles of collagen fibres of relatively small diameter are present, which are also

- perpendicular to the surface. The third layer of the central part of the wall of the glove finger consists of fibres which have the same orientation as found in the first layer.
- d. Next to this mass of collagenic fibrils, at the side of the lumen of the glove finger, there is again a thin layer of argentophylic fibrils, rich in capillaries (fig. 3).
- e. The inner surface of the glove finger, enclosing the lumen which communicates with the lumen of the cavum tympani, is covered by an epithelium composed of high columnar cells (fig. 3, 4). At certain points the cells of this epithelium are higher and form protuberances into the lumen of the glove finger (fig. 5). These protuberances are irregularly distributed over the epithelium.



*Fig. 3.* Argentophylic network and ciliated cells lining the lumen of the glove finger



*Fig. 4.* Alternating ciliated cells and secretory cells

The thick central zone of collagenous connective tissue mentioned above, contains the arteries and veins which supply the capillaries immediately underneath both epithelia.

The cells of the epithelium lining the lumen of the glove finger are about 40  $\mu\text{m}$  high. In this epithelium two types of cells are present. In one type the nucleus is invariably at the base of the cell. In the second type the nucleus is about half-way between the basis and the apex of the cells (fig. 4). The two types of cells alternate with each other. The cells with the basal nucleus have a dome shaped apex, while the other cells with their nucleus about half-way down their height, bear ciliae and have also darker cell contents in the sections stained with the Crossmon technique. The non-ciliated cells have light staining cell contents.

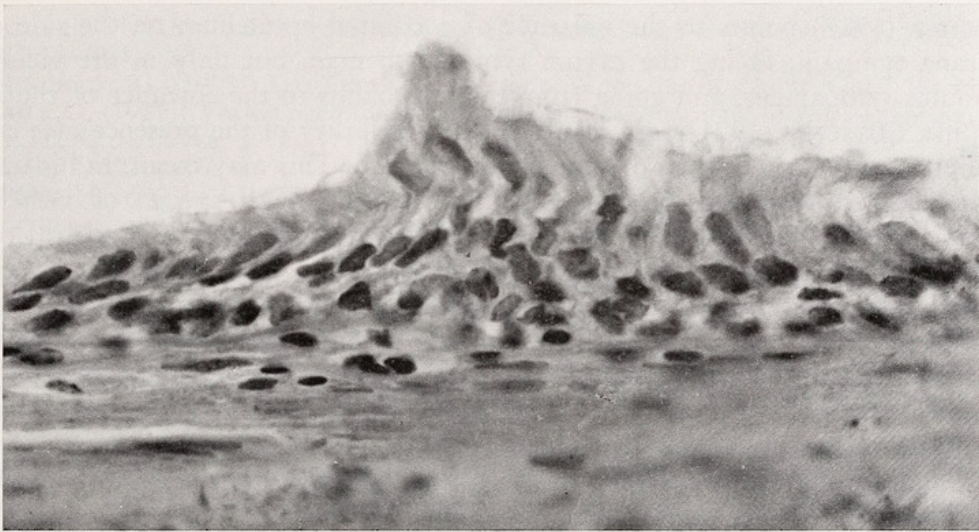


Fig. 5. Group of ciliated cells protruding into the lumen of the glove finger

In the various parts of a section, the non-ciliated cells seem to be in different stages of development of their dome shaped apex. All stages between a nearly flat apex, through intermediate stages with an elongated droplike body at the apex, to a nearly constricted apical part of the cell are present in one section. None of these cells are found to have a burst apex. It seems likely that these are secretory cells. In most of these cells the apical part has the largest diameter and often contains a large vacuole. From the apex to their basis these cells become slightly narrower, to reach at last the same diameter as the basal nucleus has.

The ciliated cells have a flat apex, present as a dark line. This line is formed by a row of granulae at which the ciliae are implanted in the cell. Each granula bears a filament. The nucleus is here situated in the upper half of the cell. At their basis the body of these cells is narrow and fits in between the two adjacent non-ciliated cells. In the dark staining ciliated cells, except for the nucleus, fine structures are hard to distinguish. This is probably due to the preservation, inadequate for these structures and to the long time of storage. However, in sections about 1  $\mu\text{m}$  thick, fibrillary structures can be distinguished, running from the apical granulae in the direction of the basal half of the cells. The light staining cells on the contrary have foamlike contents. The apical pole of the oval nucleus of these secretory cells is often flattened against the large apical vacuole.

## Discussion

In their study of the glove finger and the earplug in the Fin whale, ICHIHARA (1959) only described the histology of the epithelium covering the meatal side of this membrane, while PURVES (1955) gives a description of the earplug and its epithelium. The ciliated epithelium lining the lumen of the glove finger did not attract their attention. Neither did REYSENBACH DE HAAN (1957) mention its presence on the tympanic side of the membrana tympani and related structures in Odontoceti and Mystacoceti.

FRASER and PURVES (1954, 1960) and PURVES (1955) are of the opinion that the glove finger is a derivative of the pars flaccida of the membrana tympani. They mention the presence of a ciliated epithelium only at the entrance of the glandular ducts and on the exposed surface of the middle ear. They do not mention the presence of such an epithelium on the tympanic surface of the glove finger.

KOLMER (1927) points to the presence of a ciliated epithelium on the side of the membrana tympani, facing the cavum tympani in man, but only in the vicinity of the annulus tympanicus, and going from there in bands to the entrance of the Eustachian tube. BÜTSCHLI (1921) only mentions the possibility of the presence of a ciliated epithelium, covering the walls of the cavum tympani. This may mean, in his opinion, that the ciliated epithelium is not a regular feature in all species of vertebrates. BOENNINGHAUS (1903) described the presence of an epithelium of cylindrical cells in the various air sacs and cavum tympani in *P. phocoena*. This epithelium consists of glandular cells with dispersed groups of ciliated cells. When the lumen of the glove finger is a secondary part of the cavum tympani (VAN KAMPEN 1905), or a secondary air sac (BEAUREGARD 1894) where ciliated epithelium is present, it is reasonable that the walls of this part formed by the glove finger are covered by a ciliated epithelium, in which also secretory cells are present.

In the interpretation concerning the origin of the glove finger in the Balaenopteridae two opinions oppose each other:

- a. The glove finger is a derivative of the pars flaccida of the tympanic membrane (FRASER and PURVES 1960).
  - b. The lumen of the glove finger is a secondary part of the tympanic cavity (VAN KAMPEN 1905) or is a part of the system of accessory air sacs (BEAUREGARD 1894).
- When the opinion mentioned under a. is true one may not expect to find a ciliated epithelium covering the inner surface of the glove finger, except in the immediate vicinity of the annulus tympanicus. However, when the lumen of the glove finger is a part of the tympanic cavity or when it is a secondary air sac (b.), it is very clear that a ciliated epithelium may form the lining of the walls of such a lumen. The presence of the ciliated epithelium along the whole inner surface of the glove finger, as described above, is in favour with the opinion that the glove finger is a protrusion of the part of the tympanic membrane adjacent to the annulus tympanicus, and that it is homologous with the region described by KOLMER (1927).

Originally the development of the tympanical membrane in the Balaenopteridae is the same as in other mammalian species, and shows also the same features. However, in later stages of the foetal development the glove finger starts to develop and grows out into the external auditory meatus. So there is a possibility that the epithelium covering the walls of the cavum tympani grows out together with the growing glove finger. Hence the presence of this ciliated epithelium on the inner surface of the glove finger is not necessarily contradictory with the opinion of FRASER and PURVES (1954, 1960) that the glove finger is a part of the membrana tympani.

### Zusammenfassung

*Ein cilientragendes Epithel als innere Auskleidung des „glove finger“ im Ohr von Balaenoptera physalus Linnaeus, 1758*

Histologische Untersuchungen des „glove finger“ von *Balaenoptera physalus* zeigen, daß die innere Oberfläche mit einem Epithel aus hochzylindrischen Zellen ausgekleidet ist. In diesem Epithel sind zwei Typen von Zellen zu unterscheiden. Cilientragende Zellen wechseln mit sezernierenden Zellen ab. Ein derartiges Epithel kleidet zum Teil auch die Wände des Cavum tympani aus. Wahrscheinlich ist das Epithel zusammen mit dem sich entwickelnden „glove finger“ von hier aus gewachsen. Dadurch wird möglicherweise die Vorstellung belegt, daß der „glove finger“ aus einem Teil der Membrana tympani entstanden ist, welcher an den Annulus tympanicus grenzt, und daß sein Lumen eine Fortsetzung des Cavum tympani darstellt.

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