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The epipharyngeal bursa in the Rhinocerotidae

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(With 9 figures in the text)

The mammalian bursa epipharyngea commonly presents as an insignificant mucosal recess, not always recognisable macroscopically. In some mammalian forms, however, it is developed into an obtrusive diverticulum (sacculus epipharyngeus) extending caudally from the epipharynx between the cranial base and the pharynx roof. Among the Rhinocerotidae such an epipharyngeal saccule has been recorded for *Ceratotherium simum*. Herein it is described for the first time in *Rhinoceros unicornis*, *Diceros bicornis* and *Didermocerus sumatrensis*. Its tonsillar nature is established on morphological and histological grounds.

Contents

Introduction

The term "nasopharynx" for that segment of the mammalian respiratory tract lying directly behind the nasal fossae has been shown (Cave, 1960) to be morphologically erroneus and to be more appropriately designated "epipharynx". The conventional "bursa pharyngea" thus becomes "bursa epipharyngea" and the "pharyngeal tonsil" the "tonsilla epipharyngea".

The mammalian bursa epipharyngea is usually an insignificant median mucosal depression (often a merely microscopical evagination of the epithelium) in the epipharyngeal dorsal parieties. This mucosal dimple is evident in the foetal and immature stages of many mammalian forms, though often wholly undetectable in the corresponding adult stages. It is without ontogenetic relationship to either the cranial end of the notochord or to the cranio-pharyngeal canal, but, as Killian (1888) maintained, constitutes the focal centre of an area of mucosal specialization. Such specialization includes an aggregation of mucous (or muco-serous) glands, a localized augmentation of active lymphoid follicles and an elaborate associated vasculature—an anatomical complex constituting the epipharyngeal tonsil.

In certain mammalian forms, however, this usually insignificant mucosal recess is developed into an obtrusive gross structure in the form of a pyriform or ovoid sac (sacculus

epipnaryngeus) which proceeds caudally as a diverticulum from the epipharynx between the basioccipital bone above and the pharynx roof below.

The simple type of epipharyngeal bursa is the commonest among mammals. The specialized saccular form of bursa has been recorded for *Ailuropoda melanoleuca* (Davis, 1964; Cave, 1965) and for *Ursus arctos*, *Ursus americanus*, *Ursus horribilis*, *Melursus ursinus* and *Helarctos malayanus* (Mayer, 1842; Rapp, 1839; Alix, 1877; Boulart, 1885).

Contrariwise an epipharyngeal saccule was not observed in *Canis familiaris*, *Nasua rufa*, *Viverra civetta*, *Herpestes griseus*, *Paradoxurus trivirgata*, *Mephitis mephitica*, *Felis domestica* and *Lutra vulgaris* (Killian, 1888) nor in *Procyon lotor* and *Ailurus fulgens* (Davis, 1964).

Among non-carnivorous mammals an epipharyngeal saccule has been briefly reported for *Giraffa camelopardalis*, *Okapia johnstoni*, *Rhinoceros unicornis* and *Ceratotherium simum* (Cave, 1965). The present notice augments knowledge of this type of epipharyngeal bursa in the Rhinocerotidae, with special reference to its occurrence in *Diceros bicornis* and in the rare *Didermocerus sumatrensis*.

Materials and methods

The pharynx and adnexa were removed as completely as possible from the following rhinoceros specimens in the fresh, uninjected state and were formalin-preserved until subsequent dissection:

Indian rhinoceros (*Rhinoceros unicornis*)				
R 45	♂ ("Hush")	15 years	1945	Whipsnade Zoo
R 21	♂ ("Mohan")	18 years	1961	Whipsnade Zoo
Black rhinoceros (*Diceros bicornis*)				
R 19	♀	2 years	1960	Whipsnade Zoo
R 24	♂	4 years	1962	Whipsnade Zoo
R 27	♀ ("Lorna")	18 years	1963	London Zoo
R 68	?	foetus	1968	Kenya (wild)
White rhinoceros (*Ceratotherium simum*)				
R 20	♂	3 years	1964	Whipsnade Zoo
R 162	♀ ("Bebe")	11–12 years	1964	London Zoo
Sumatran rhinoceros (*Didermocerus sumatrensis*)				
R 72	♀ ("Subur")	13 years	1972	Copenhagen Zoo

(This animal, one of five captured (1959) in the Little Siak River district, Riau, Sumatra, was exhibited in the Copenhagen Zoo (1959–1972): a second female from this same catch was exhibited in the Basel Zoo (1959–1961). When available for anatomical examination the viscera of this second animal lacked the pharynx and throat parts.)

Histological examination was made, when practicable, of the wall of the epiphangeal saccule. Whole thicknesses of the wall were paraffin-blocked, cut at a 10 μm thickness and stained with the customary laboratory stains.

Observations

Indian rhinoceros

In specimen R 45 the soft palate and pharynx were mutilated during excision, as is so often unavoidable during the evisceration of large and unwieldy carcases. Subsequent examination of the detached pharynx, however, disclosed a small irregular patch of

epipharyngeal mucosa adherent by connective tissue to that organ's dorsal wall, immediately caudad of the isthmus epipharyngo-pharyngeus. This mucosal patch displayed a few longitudinal grooves and mammillated plicae and contrasted strongly in appearance with the muscular pharyngeal parieties: it was unmistakably the ventral remnant of a destroyed epipharyngeal saccule.

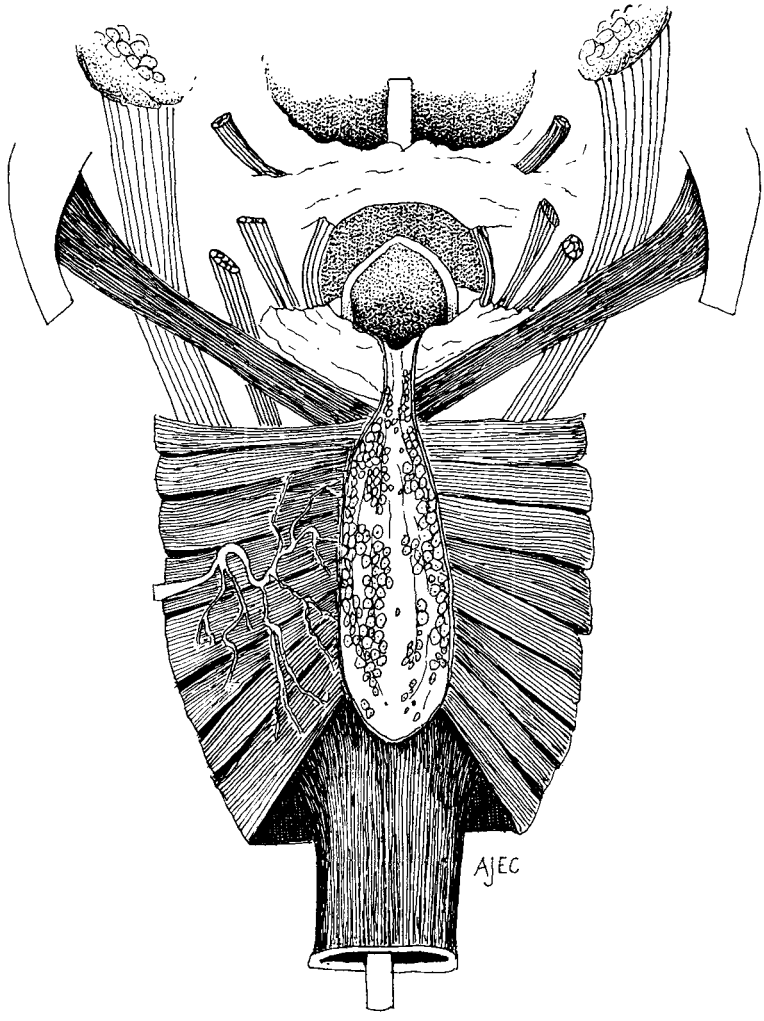

FIG. 1. *Rhinoceros unicornis*, ad. ♂ (specimen R 21). Dorsal aspect of soft palate, epiglottis, pharynx, etc., showing (opened) epipharyngeal bursa *in situ*. From a dissection sketch after some separation of the parts. The bursa is depicted as entire.

In specimen R 21 the ventral wall and torn fundus of such a saccule remained *in situ* upon the roof of the excised pharynx, immediately caudad of the epipharyngo-pharyngeal isthmus. Its dorsal wall remained firmly adherent to the under surface of the basioccipital. The general disposition of this saccule is indicated in the accompanying dissection sketch (Fig. 1), made after some disturbance of the parts. The saccule had a thin fibrous wall and

was lined by a more-or-less longitudinally plicated mucosa which bore a pseudo-stratified columnar (respiratory) type of epithelium and was provided with an abundance of small glands. These last were of mixed mucous and serous (salivary) type, with ducts discharging either directly into the saccule lumen or into epithelial crypts in the mucosa. A rich mucosal vasculature was characterized by an extreme number of small thick-walled arteries. Both the mucosa and the submucosa were heavily infiltrated by diffuse lymphoid tissue and lymphoid tissue was more densely concentrated around the bloodvessels.

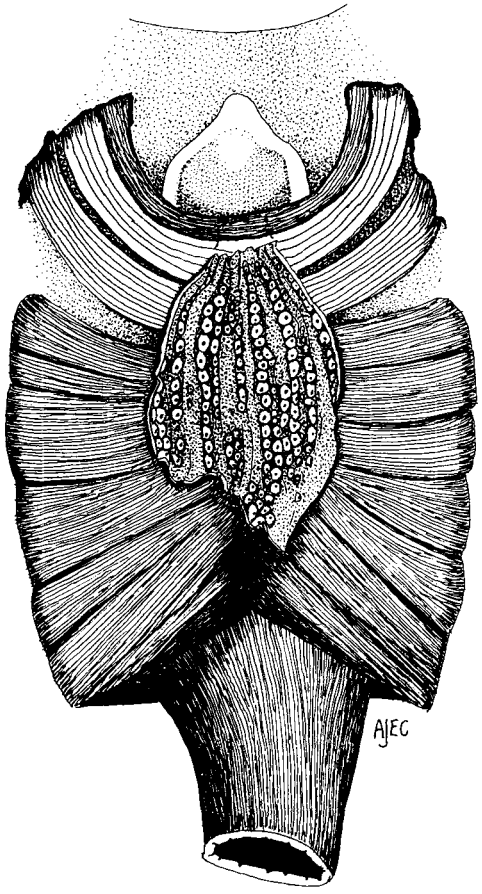

FIG. 2. *Diceros bicornis*, juv. ♂ (specimen R 24). Dorsal aspect of pharynx and oesophagus to show ventral portion of an epipharyngeal bursa *in situ*.

Black rhinoceros

In specimen R 19 part only (ventral parietes) of an epipharyngeal saccule was found adherent to the roof of the excised pharynx. This saccule remnant lay immediately caudad of the isthmus epipharyngo-pharyngeus and was attached to the pharynx roof by a median, septum-like condensation of the local (retropharyngeal) fascia which accommodated a number of relatively large veins. The thin fibrous saccule wall was lined by a longitudinally wrinkled mucosa, mammillated in places and bearing a respiratory (pseudo-stratified

columnar) type of epithelium. On and between the mammillary eminences appeared the ostia of the ducts of small mucous glands lying deeply in the mucosa. The entire thickness of the mucosa was heavily infiltrated by lymphoid tissue in diffuse form, whilst around the gland ducts and the very numerous mucosal arteries, lymphoid tissue was present in denser concentrations.

In specimen R 24 a greater portion (ostium, neck, body, fundus) of the ventral parietes of a mutilated epipharyngeal saccule was preserved with the pharynx (Fig. 2). This thin-walled fibrous diverticulum extended caudally from the isthmus epipharyngo-pharyngeus

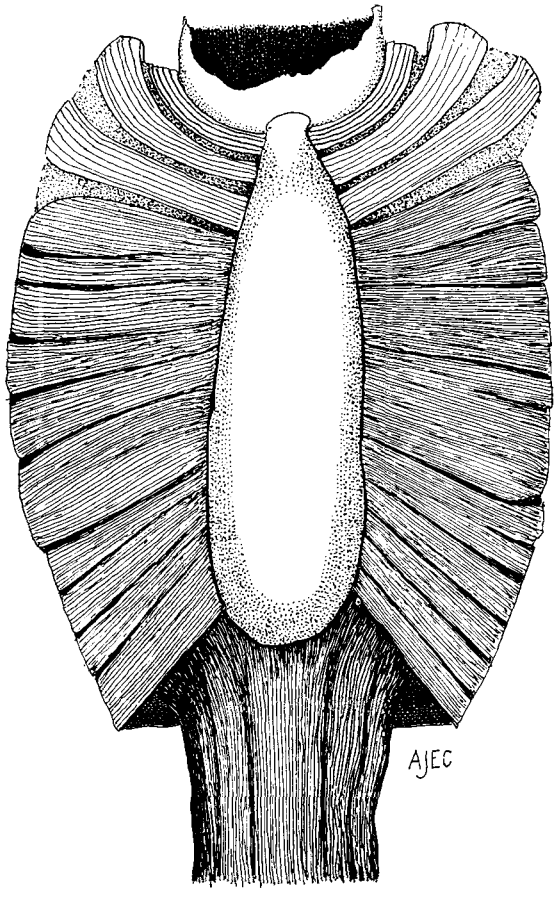

FIG. 3. *Diceros bicornis*, ad. ♀ (specimen R 27). Dorsal aspect of pharynx showing cuff of epipharyngeal mucosa in continuity with an epipharyngeal bursa.

over the entire pharynx roof, to which it was loosely bound by ligamentous condensations of the retropharyngeal fascia, in which numerous and fairly large veins were conspicuous. The saccule mucosa manifested a pseudo-stratified columnar epithelium, which descended as numerous branching crypts into the mucosal depths. Some of the longitudinal mucosal plicae present were mammillated, others not: gland-duct ostia were discernible both upon and between the plicae. In the deeper layers of the mucosa mucous and muco-serous

glands abounded. Lymphoid tissue infiltrated the mucosa and submucosa generally, both as a diffuse lymphocytic infiltration and as dense concentrations of lymphoid tissue around the gland ducts and the numerous bloodvessels.

In specimen R 27 an epipharyngeal saccule (Fig. 3) was largely preserved in continuity with a strip of epipharynx mucosa. This saccule, of elongate pyriform shape, extended diverticulum-wise and caudally from the epipharynx between the basis cranii dorsally and the pharynx roof ventrally. Its ostium lay immediately above the arcus epipharyngo-pharyngeus, its body above the pharynx and its fundus above the juxta-pharyngeal portion of the oesophagus. The saccule was adherent dorsally to the basioccipital: ventrally it was less firmly attached to the pharynx by short ligamentous condensations of retropharyngeal

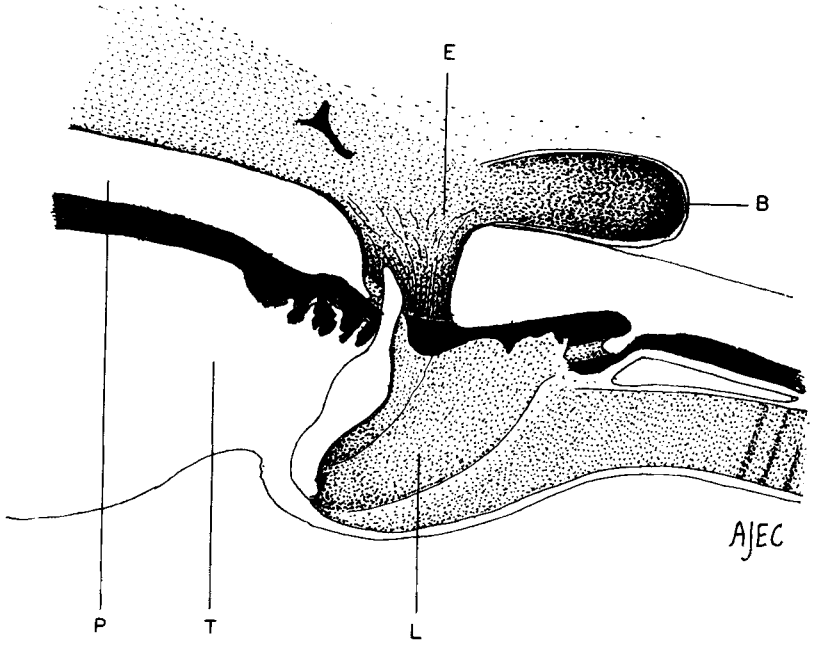

FIG. 4. *Diceros bicornis*, foetus (specimen R 68). Sagittal section through palate (P), tongue (T), larynx (L) and epipharynx (E) to show epipharyngeal bursa (B).

fascia, which supported a number of tortuous and relatively large veins, some of which clearly received tributaries from the saccule wall. The saccule mucosa bore a typical epipharyngeal (pseudo-stratified columnar) epithelium which formed numerous deep and branching crypts: it was irregularly plicated longitudinally, some of the plicae being mammillated. Gland-duct ostia opened in considerable numbers both upon and between the plicae. The extremely vascular mucosa showed great abundance of blood vessel of small and of moderate size and a plenitude of both large and small lymphatic vessels. The deeper mucosal layers were characterized by an elaborate equipment of small glands of salivary (mucous, serous, muco-serous) type. The entire mucosa was heavily infiltrated by lymphatic tissue, which tended to become notably concentrated around the gland-ducts and the bloodvessels.

Specimen R 68 was a dismembered foetus of unknown sex and imprecise age. Sagittal section of the head revealed the presence, in the canonical situation, of a welldeveloped epipharyngeal saccule. Histological examination of this saccule was impracticable, but its topographical relationships are indicated in the accompanying diagram (Fig. 4). The prominent arcus palato-epipharyngeus embraced the plica aryepiglottidea and the free (superior) extremity of the epiglottic cartilage effected and occupied a transverse sulcus on the dorsum of the soft palate.

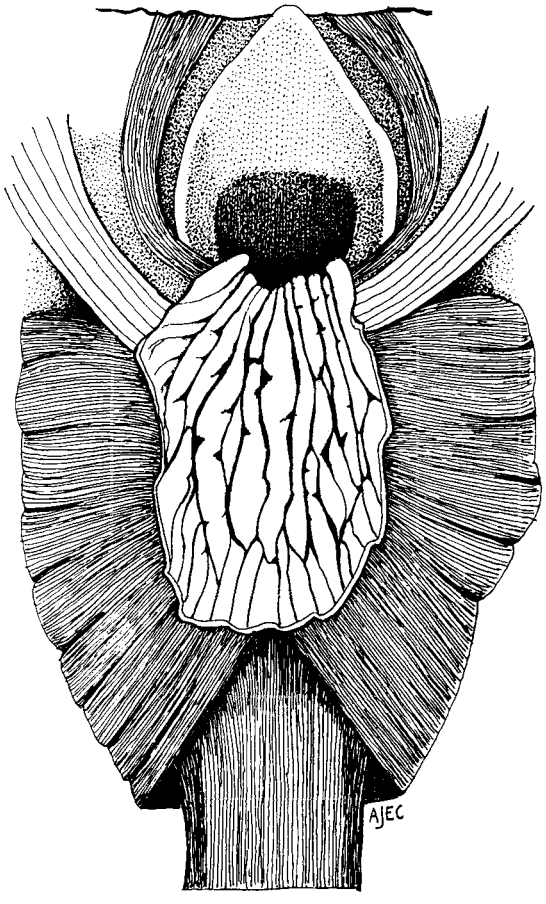

FIG. 5. *Ceratotherium simum*, juv. ♂ (specimen R 20). Dorsal aspect of pharynx and associated parts to show ventral portion of an epipharyngeal bursa *in situ*.

White rhinoceros

In specimen R 20 the anterior portion of the ventral parietes of a mutilated epipharyngeal saccule was adherent to the pharynx roof immediately caudad of the isthmus epipharyngopharyngeus, secured in place by a ligamentous condensation of the retropharyngeal fascia (Fig. 5). This saccule remnant showed a thin, purely fibrous external wall, lined by a moderately thick, vascular, longitudinally plicated mucosa. Many plicae displayed a discontinuous surface mammillation due to the presence of subjacent lymphoid follicles.

Gland-duct ostia were abundant both upon the plicae (often centrally in a mammilliform eminence) and in the intervening furrows. The saccule was short-necked: its body extended caudally over the entire pharynx roof and its fundus overlay the juxta-pharyngeal portion of the oesophagus.

In specimen R 162 the virtually entire epipharyngeal saccule (Fig. 6) was removed with the pharynx, to the roof of which it was attached by a median condensation of retro-pharyngeal fascia. In and upon this fascial arrangement relatively large bloodvessels were discernible—including a triple arterial supply to the saccule and numerous veins from the saccule draining directly or indirectly into the pharyngeal venous plexus. The saccule ostium lay immediately above the isthmus epipharyngo-pharyngeus, the neck expanded rapidly into the pyriform body (overlying the whole length of the pharynx roof) and the fundus overlay the juxta-pharyngeal portion of the oesophagus (Fig. 7). The thin, tough fibrous wall of the saccule was lined by a thick, vascular mucosa, disposed principally as longitudinal plicae: many such plicae were prominently mammillated and both upon and between the plicae appeared the ostia of great numbers of gland-ducts.

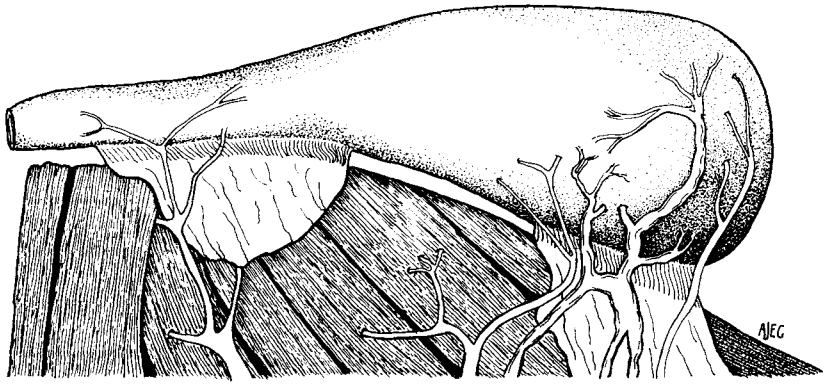

FIG. 6. *Ceratotherium simum*, ad. ♀ (specimen R 162). Saccular epipharyngeal bursa *in situ* upon pharynx roof, with remnants of ligamentous fascial attachment thereto and local bloodvessels.

Histologically the saccule wall was purely collagenous. The saccule epithelium was of the pseudo-stratified ciliated variety, indicative of respiratory function: it yielded no evidence of taste buds or other sensory epithelial organs, but displayed numerous goblet cells and a well-developed basement membrane: in places it was heavily impregnated with lymphocytes. It gave off numerous large crypts which descended, branching dichotomously, to the glandular layer of the mucosa, the principal and the subsidiary crypts receiving some of the ducts of the salivary-type glands in the mucosa depths.

The subepithelial zone of the mucosa was heavily invested by invasive lymphoid tissue. A general, diffuse lymphocytic infiltration was augmented by the presence of great numbers of lymphoid secondary nodules. These nodules were the most obtrusive histological feature of the mucosa, accounting for the surface mammillation of the saccule plicae and were so large as to be recognizable in the stained sections by the naked eye. Individual nodules were liberally permeated by an abundance of small arteries.

Deep to the lymphoid nodule zone occurred an almost continuous layer of small salivary-type glands, seemingly inter-connected by extremely tenuous fibrous strands:

additional glands of like nature lay between the lymphoid secondary nodules. Some of these glands were of the mucous, others of the serous and others again of the muco-serous variety. Their ducts terminated variously: some opened into the saccule lumen, others into the main crypts and others into the crypt branches: these ducts usually took the shortest

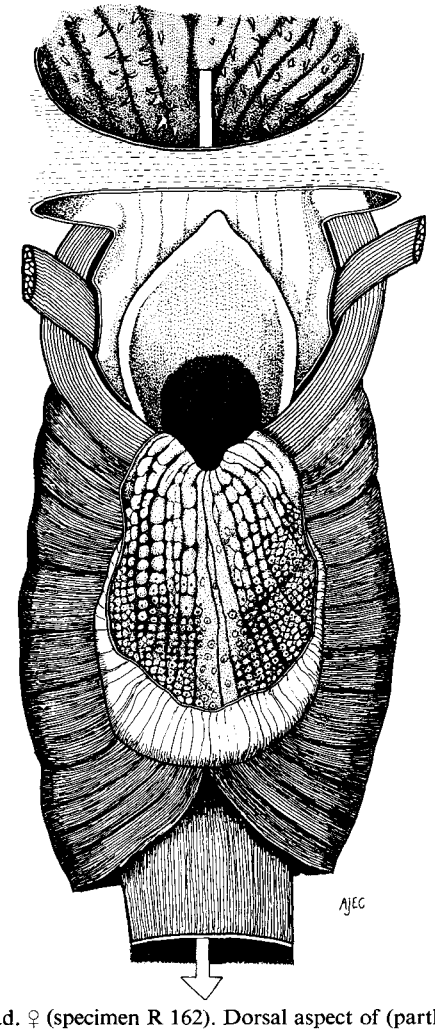

FIG. 7. *Ceratotherium simum*, ad. ♀ (specimen R 162). Dorsal aspect of (partly sectioned) soft palate, epiglottis, pharynx and oesophagus with opened epipharyngeal bursa *in situ*. The bursa fundus is reflected anteriorly to expose the otherwise covered oesophagus. The arrow passes from the mouth cavity through the pharynx into the oesophagus.

course available to a free surface, coursing variously around, between or through the secondary nodules in their passages thereto (Fig. 8).

The mucosa as a whole revealed a vasculature of almost incredible richness and complexity and was essentially a blood vascular spongework impregnated by lymphoid tissue

in relatively enormous quantity. It abounded in great numbers of small, medium and large arteries and veins and of both large and small lymphatic vessels. Some of the large arteries were notably thick-walled and arteries of spiral disposition were observable in particular relation to the lymphoid secondary nodules—an arrangement associated perhaps with periodic turgescence of the mucosa. Almost all arteries were conspicuously "lagged" by condensations of surrounding lymphocytes. Blood vessels were particularly abundant in relation to the salivary-type glands and to the lymphoid secondary nodules. The presence of extravascular erythrocytes indicated a haemolymph gland function on the part of the saccule mucosa.

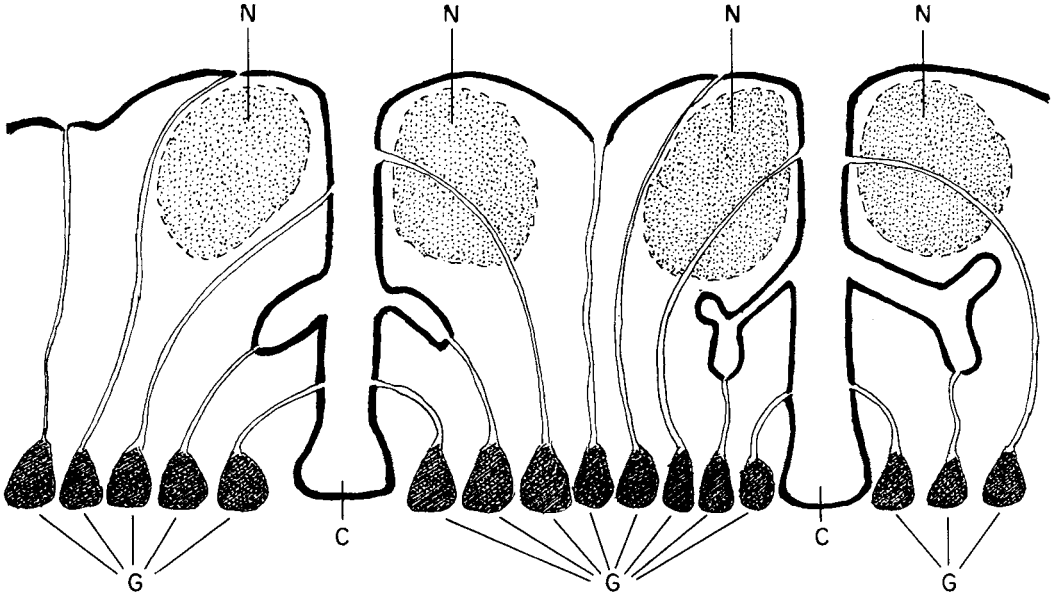

FIG. 8. *Ceratotherium simum*. Histological details of epipharyngeal bursa mucosa. Showing branching crypts (C), layer of small salivary type glands (G) and lymphoid secondary nodules (N), as also the variable mode of termination of the gland ducts. Diagrammatic.

The sensitivity of the mucosa was emphasized by the abundance and general distribution of nerve trunks, so numerous in places as to outnumber the arteries. These nerve trunks were composed of numerous fine fibres admixed with fewer large fibres, all heavily myelinated and plainly of sensory nature. No nerve ganglia were anywhere observable. In a series of high-power fields the relative incidence of arteries, veins, lymphatics and nerve trunks was as follows:

H.P. field	1	2	3	4	5	6	7	8	9
No. of arteries	1	2	1	2	1	5	2	2	1
No. of veins	5	0	2	2	3	4	3	6	2
No. of lymphatics	8	0	4	6	0	4	0	0	1*
No. of nerve trunks	6	4	11	0	1*	1	0	1*	0

*, Particularly large.

Sumatran rhinoceros

During the evisceration of specimen R 72 special attention was paid to the post-nasal region, so that the epipharyngeal mucosa was largely secured in undamaged condition and in continuity with an obtrusive epipharyngeal saccule. This last was of elongate pyriform shape and situated between the basioccipital dorsally and the pharynx roof ventrally: to the pharynx it was attached by ligamentous condensation of the retropharyngeal fascia, which formed practically a median septum and exhibited a number of relatively large veins, radicles of the pharyngeal venous plexus (Fig. 9).

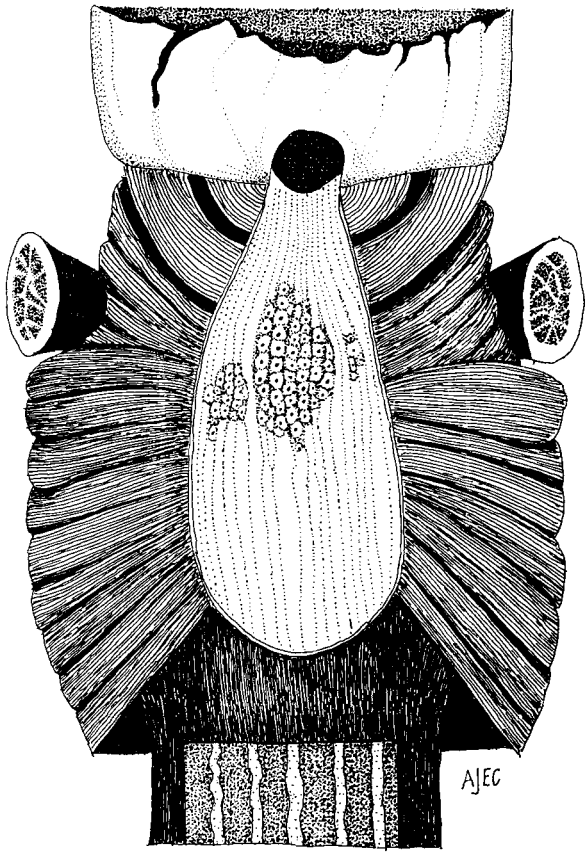

FIG. 9. *Didermocerus sumatrensis*, old ♀ (specimen R 72). Dorsal aspect of pharynx and epipharynx showing ventral wall of epipharyngeal bursa *in situ* with centrally situate lymphoid mass (epipharyngeal tonsil). Oesophagus unduly flattened and windowed to expose mucosal rugae. Thyro-hyals sectioned.

The saccule was some 110 mm long with a maximum diameter of approximately 40 mm. Its ostium communicated with the epipharynx medio-dorsally to the isthmus epipharyngo-pharyngeus, its neck expanded rapidly into a fusiform body which terminated posteriorly in a fundus overlying the beginning of the oesophagus. The saccule wall, thin and entirely fibrous, was lined by a mucosa of typically epipharyngeal type (i.e. one bearing a pseudo-stratified ciliated columnar epithelium) which sent crypts down into the subepithelial layers. Macroscopically the mucosa was longitudinally plicated and the ostia of gland

ducts were visible both upon and between the plicae. Lymphoid tissue in diffuse form occurred generally throughout the mucosa and submucosa. Lymphoid tissue in the form of secondary nodules was largely confined to a single, large, partly-subdivided mass situate in the central area of the saccule ventral wall. Here the mucosal surface was typically mammillated and the mammillary eminences displayed the ostia of the ducts from small glands of salivary type situated in the mucosa below the level of the lymphoid nodules. Elsewhere the mucosal plicae were non-mammillated. With this exception the structure of the epipharyngeal saccule in this specimen of *Didermocerus* differed in no essential with that observed in specimens of *Rhinoceros unicornis*, *Diceros bicornis* and *Ceratotherium simum*. It would seem that in the present specimen at least the epipharyngeal tonsil is of more compact and localized disposition than in other rhinoceros forms, but general conclusions concerning the *Didermocerus* structure cannot be based upon the findings in a solitary specimen.

Discussion

A bursa epipharyngea of single saccular form having been shown to occur in the Indian, Sumatran and African rhinoceroses, a reasonable presumption is that such a structure is present also in the vanishing Javan rhinoceros (*Rhinoceros sondaicus*)—unavailable for present study—and constitutes a canonical anatomical feature throughout the extant Rhinocerotidae. In the four rhinoceros forms reviewed above, the bursa epipharyngea exhibits a uniformity of configuration, constitution and topography. Essentially its mucosa represents an extremely rich and elaborate vasculature heavily impregnated with active lymphoid tissue in both diffuse and nodular form in association with numerous small glands of salivary type. This physiologically active lympho-glandular apparatus is located by confinement within a fibrous envelope, a replica of arrangements in the palatine (faucial) tonsil. On anatomical and histological grounds the tonsillar nature of the epipharyngeal bursa is self-evident. Its saccular disposition may well represent a mechanical device to accommodate the maximum aggregation of lymphoid tissue within the confines of a limited space.

In the single *Didermocerus* specimen examined, the bursal lymphoid tissue tended to a greater degree of intra-saccular concentration than obtained in the remaining rhinoceros species examined, but this finding may represent nothing more than a casual and minor anatomical variation and is in nowise evidence of generic or specific distinction.

The bursa epipharyngea of the Rhinocerotidae has its counterpart in the Equidae, as the canonical "recessus pharyngeus" of the horse (*Equus caballus*) and ass (*Equus asinus*). This median recess is described by Lesbre (1922) as proceeding from the epipharynx as "un cul de sac de sa muqueuse", which, however, he misinterprets as a relic of the embryonal cranio-pharyngeal canal. Bradley (1946) describes (not very satisfactorily) as constant in the horse a median blind recess, of variable size, which protrudes from the epipharynx "into a gap between the pharyngeal muscles" and establishes direct contact with the Eustachian tube diverticulum (guttural pouch).

Nothing appears to have been reported to date concerning the presence of an epipharyngeal bursa in the Tapiridae.

Gratitude is hereby tendered to the Council of the Zoological Society of London for the generous provision of rhinoceros research material, to Dr W. R. Cook, University of Glasgow

Veterinary School for the gift of a Kenyan *Diceros* foetus, to Dr Magnus Degerbøl, Zoology Museum, and Professor K. G. Wingstrand, Institute of Comparative Anatomy, University of Copenhagen, for the considerate procuration and presentation of *Didermocerus* material and to Dr F. J. Aumonier for professional opinion upon histological preparations.

REFERENCES

Alix, E. (1877). Sur les poches pharyngiennes de l'ours jongleur (*Ursus labiatus*). *Bull. Soc. philomath. Paris* (7) **1:** 47–48.

Boulart, R. (1885). Note sur les poches pharyngiennes des ours. *J. Anat. Physiol., Paris* **21:** 535–537.

Bradley, O. C. (1946). *The topographical anatomy of the head and neck of the horse.* 2nd ed. (revised T. Grahame). Edinburgh: Green.

Cave, A. J. E. (1960). The epipharynx. *J. Lar. Otol.* **74:** 713–717.

Cave, A. J. E. (1965). The bursa pharyngea in the Giant panda (*Ailuropoda melanoleuca*). *Nature, Lond.* **208:** 865–867.

Davis, D. D. (1964). The Giant panda. A morphological study of evolutionary mechanisms. *Fieldiana zool. Mem.* **3:** 1–337.

Killian, G. (1888). Ueber die Bursa und Tonsilla Pharyngea. *Morph. Jb.* **14:** 618–711.

Lesbre, F.-X. (1922). *Précis d'anatomie comparée des animaux domestiques* **1**. Paris: Baillière.

Mayer, A. F. J. C. (1842). *Neue Untersuchungen aus dem Gebiete der Anatomie und Physiologie.* Bonn.

Rapp, W. v. (1839). Ueber die Tonsillen. *Mueller's Arch. Anat. Physiol.* **1839:** 189–199.