



CHAPTER 6

GENERAL CONCLUSIONS



The upper digestive tract of the emu has received little attention in the past, with only the tongue and laryngeal mound being briefly described and the oesophagus documented in two specimens. The emu is deemed a commercially important bird and thus a sound knowledge of the basic biology of this bird is imperative. This study described the detailed gross anatomy and histology of the oropharyngeal cavity and the structures and features therein as well as the proximal oesophagus. The morphology of the surface features was described using scanning electron microscopy.

The oral and pharyngeal cavities of the emu, as in other birds, could not be distinguished from one another using recognisable morphological features and thus formed one cavity, the **oropharynx**. This cavity was dorso-ventrally flattened in the closed gape and bounded laterally by the tomia. Both the floor and roof of the cavity were divided into rostral aglandular pigmented regions, lined by a keratinised stratified squamous epithelium, and caudal non-pigmented glandular regions, lined by a non-keratinised stratified squamous epithelium. The non-pigmented floor housed the tongue and laryngeal mound. The non-pigmented roof housed the choana and merged with the two pharyngeal folds, separated at their origin by the infundibular cleft. Numerous Herbst corpuscles were located in the connective tissue in the pigmented regions. Thus these areas would have a high sensitivity to touch and texture. This may be an important function considering the investigative nature of this bird as well as being important for food selection. Herbst corpuscles are a common feature in the ratite oropharynx, and are described in the greater rhea, ostrich and kiwi. The oropharynx of the emu therefore reflects the general pattern of the ratites with a few modifications and differences.

The emu has prominent mandibular and maxillary **nails**, features only previously identified in pelicans, gulls and ducks. The ostrich also has such structures, thus the ratites can be included amongst the birds with nails on the bill tips. The **serrated tomia** of the mandible were a unique feature of the emu. Such structures are also present in the ostrich but are very rudimentary. It



has been previously stated that the emu has no need for a strong bill due to its diet. However, the nails and serrations provide a strong gripping and tearing instrument. The numerous Herbst corpuscles also provide a high degree of sensitivity.

The non-pigmented floor displayed many small **fol**ds and two larger, flat glandular folds. Numerous nodules were also seen, representing lymphoid tissue aggregations. The ingestion method of the emu has been previously described, where the food travels from the bill tips to the oesophageal entrance, thus bypassing structures in the oropharynx. To allow the passage of ingesta through the dorso-ventrally flattened oropharynx, the tongue is used to depress the oropharyngeal floor, thus enlarging the cavity. The folded nature of the floor would allow for such enlargement. During fluid ingestion, the folded floor would be distensible, allowing for the accumulation of fluid in the oropharynx before lifting the head to transport fluid to the oesophagus.

Following the general trend in ratites, the emu **tongue** is greatly reduced in comparison to the bill length and is specifically adapted for swallowing during the cranioinertial method of feeding employed by palaeognaths. It was not only the shape of the tongue that differed between ratites, as previously reported, but also the colour of the tongue, the appearance of the tongue margins and root, the length of the tongue in comparison to the bill, and the shape of the *paraglossum*. Previously, the only function attributed to the emu tongue was that of retraction during swallowing. However, it was seen from this study that the tongue has at least four main functions, namely: 1.) digestive (role in swallowing), 2.) sensory (taste and touch), 3.) immunological and 4.) mechanical protection (by virtue of mucus-secretion).

Although the **laryngeal mound** of the emu has been previously described, important differences were noted in this study. The laryngeal mound has been depicted as being similar to that of the ostrich, although it clearly differs. The glottis is wide rostrally and narrows caudally. There are no papillae on the laryngeal mound. The three to five longitudinal folds lying ventrally in the laryngeal entrance have not been previously noted. Although the function of these folds was not determined in this study they seem to be a unique feature of the emu compared to the other ratites. The glottis of ratites is relatively larger in comparison to that of other bird families. Birds do not possess an epiglottis; however, due to the wide glottis present in the emu and ostrich, it appears possible that the tongue possesses special modifications to assist in closing the glottis during ingestion. The shape and location of the emu tongue root would indicate that it may fulfil



such a function. The laryngeal mound of the emu performs both a respiratory and digestive (swallowing) function. The crico-arytenoid glands are located on the emu laryngeal mound. Their mucus-secretion would assist in the digestive function of the mound and contribute to lubrication of the oropharynx. Herbst corpuscles, attributing a sense of touch to the laryngeal mound, are also present. The laryngeal mound differs between the ratites with regard to shape, glottis and papillae.

In the emu the **choana** is triangular with a wide, median grooved ridge separating the two oblong internal nares. The shape of the choana differs between the ratites, with that of the emu appearing unique. The median groove of the ridge continues caudal to the choana as the **infundibular cleft**. The infundibular cleft in the emu was less defined than that of the ostrich.

The two large **pharyngeal folds** of the emu were similar to those of the ostrich and displayed a high density of glandular and lymphoid tissue. The emu had, additionally, a small tissue projection on the caudo-lateral edge of the folds, composed almost entirely of lymphoid tissue, which together with the pharyngeal folds, effectively formed pharyngeal tonsils (*lymphonoduli pharyngeales*). The shape and size of the pharyngeal folds differ between the ratites. The pharyngeal folds of the emu fulfil a mechanical function of closing off the oesophageal entrance during respiration, an immunological function and a protective function (attributed to mucins supplied by the numerous mucus-secreting glands located in the folds).

The observations of the **proximal oesophagus** confirmed the features previously described for the emu oesophagus as well as for other ratites and birds in general. Additionally, the identification of taste buds within the epithelium was a previously unreported observation. This study is the first report of taste buds in a ratite oesophagus. As food is transported to the oesophageal entrance and largely bypasses the structures in the oropharynx, the location of taste buds in the proximal oesophagus seems a logical finding as the emu may discriminate the food while swallowing and thus be able to decide whether more of that particular food should be ingested. The oesophagus of the emu shows three main adaptations for the ingestion of large food particles: 1.) the diameter is relatively large, 2.) the mucosa is longitudinally folded allowing great distensibility and 3.) the numerous mucous glands secrete copious amounts of mucus to lubricate the lumen and food for ease of transport.



The following groups of **salivary glands** were identified: caudal intermandibular, lingual (dorsal, rostro-ventral, caudo-ventral, frenular and radical), crico-arytenoid, oral angular, caudal palatine, pharyngeal and oesophageal. The mucous glands were small, simple tubular and large, simple branched tubular in the oropharynx, and simple tubular (occasionally branched) in the oesophagus. The main function of the glands is mucus production which contains mucins. Mucins provide protection from desiccation and mechanical damage, help maintain cellular water balance, provide lubrication and are antimicrobial in action. Sticky saliva also assists in the backward propulsion of food and prevents regurgitation.

Herbst corpuscles in the emu were most numerous in the dermis of the bill skin. They varied in size and grouping, with most occurring singly and others arranged in longitudinal chains. They occurred in the connective tissue underlying the pigmented oropharyngeal roof and floor. In the non-pigmented glandular regions they were associated mainly with the larger glands. Their numbers diminished in a caudal direction. They were absent from the pharyngeal folds and proximal oesophagus only. Herbst corpuscles also occur in the ostrich, greater rhea and kiwi oropharynx. Their ubiquitousness in the emu oropharynx indicates that the upper digestive tract is highly sensitive to touch and thus may play an important role in food selection by virtue of texture.

The **lymphoid tissue** in the emu oropharynx and proximal oesophagus occurs mainly as accumulations of diffuse lymphoid tissue. This tissue was located in the connective tissue at the junction between the pigmented and non-pigmented roof; ventrum, frenulum and root of the tongue; the non-pigmented oropharyngeal floor; the rictus; oesophagus; and particularly in the pharyngeal folds. In the glandular areas, the diffuse lymphoid tissue was mostly associated with the ducts of the large glands. The epithelium overlying the lymphoid tissue often showed a change from a stratified squamous epithelium to a pseudostratified ciliated columnar epithelium. Only *Lymphonoduli pharyngeales* (pharyngeal tonsils) were identified in the emu.

Taste buds in the emu were isolated structures found in the epithelia of the non-pigmented oropharyngeal floor, tongue root and proximal oesophagus. They were clearly demarcated from the surrounding epithelium, displayed a taste pore and contained vertically oriented elongated cells. These presumably represented the sensory and supporting cells which could not be distinguished from one another by the staining techniques used in this study. This is the first report of taste buds in the emu and ratites in general.



SEM confirmed a number of features noted histologically and provided corroboratory evidence regarding the distribution of the different types of glands. The keratinised regions of the rostral parts of the oropharynx displayed sheets of desquamating cells which revealed a pattern of microridges on their surface. The non-keratinised regions of the oropharynx revealed both individual desquamating surface cells, which displayed a complex surface pattern of microplicae, or regions of clearly demarcated cells, which displayed a surface adorned with microvilli. Cilia were present in the ducts of some of the large glands, as well as on the tongue ventrum near the opening of glands. Openings in the surface were round to oval and were generally lined or bordered by concentrically arranged cells. Large openings representing the ducts of the underlying large, simple branched tubular glands, often displayed cilia and emerging mucus-secretions. Small openings, lined and surrounded by dense microvilli, represented the openings of the underlying small simple tubular (sometimes branched) glands. Larger openings were generally evenly distributed, whereas the smaller openings mostly occurred in groups, or near the large openings. No meaningful comparisons can be made to other ratites regarding surface morphology of the oropharynx and proximal oesophagus due to the absence of detailed information in previously published works.

