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A peculiar association: the skin and the subcutaneus diverticula of the Southern Screamer (*Chauna torquata*, Anseriformes)

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Abstract

The aim of this work is to describe for the first time the skin and the subcutaneous diverticula at histological level (by light microscopy) of the Southern Screamer *Chauna torquata*. We found that the main distinguishing features of the skin were the presence of deep and branched epidermal invaginations whereas in the dermis abundant elastic fibers were found. These skin features could provide a great stretchability to the skin which, in turn, are related to the change of volume that may experience the subcutaneous diverticula.. Since screamers are flying birds that soar to great heights, the presence of subcutaneous diverticula together with another anatomical features (like a great skeletal pneumaticity) could favor a body mass reduction and an optimization in its mode of locomotion.

Key words

Pneumaticity, epidermis, dermis, air sacs, Aves, Anhimidae.

Introduction

The structure and organization of the avian skin has been mainly studied in domestic birds (Matoltsy, 1969; Lucas & Stettenheim, 1972; Hodges, 1974), but little is known on the skin of wild birds. The screamers belong to the Anhimidae (Anseriformes), this family includes only three species and they all are large, robust birds that inhabit open areas near marshes and watersides in the Neotropics. *Chauna torquata* (commonly known as the southern screamer) is the only one species that inhabit Argentina (Narosky & Izurieta, 2003). Screamers present some peculiar anatomical characters such as the absence of apteria and uncinate processes (Carboneras, 1992), an extreme skeletal pneumaticity (O'Connor, 2004) and are the only Anseriformes with the presence of a system of subcutaneous diverticula (also known as pneumatic diverticula, subcutaneous air cells or superficial air cavities) (Crisp, 1864; Garrod, 1876). These structures are extensions of the air sac system, which are arranged between the skin and muscle. In Screamers, they cover the entire body and are filled with air (Garrod, 1876; Demay, 1940). While the subcutaneous diverticula have already been macroscopically described by several

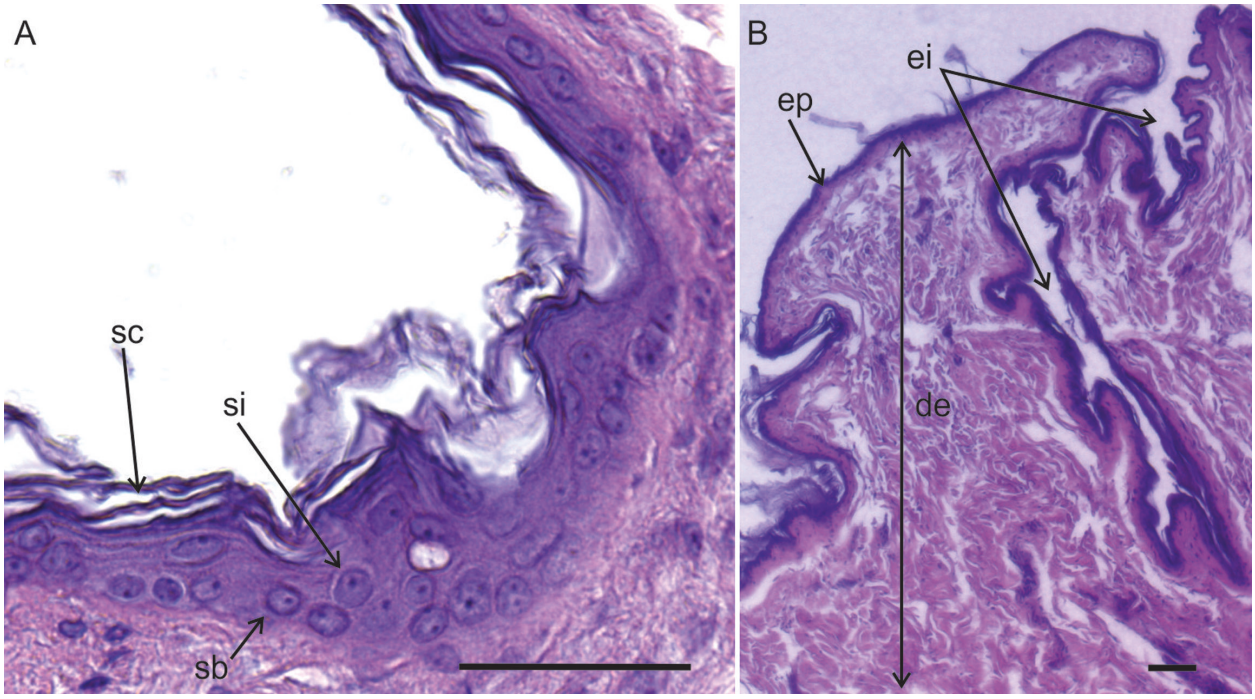


Fig. 1. Structure of epidermis: (**A**) Hematoxylin and Eosin stain showing the general structure of epidermis, (**B**) Low magnification section showing the epidermal invaginations, de: dermis, ei: epidermal invagination, ep: epidermis, sco: stratum corneum; si: stratum intermedium, sb: stratum basale. Scale bar: 40 µm.

authors (Crisp, 1864; Garrod, 1876; Demay, 1940), their histological structure (in addition to the histology of the skin) has not been studied. The aim of this work is to provide for the first time a histological description of the skin and subcutaneous diverticula of *Chauna torquata* and further elucidate on their function.

Materials and Methods

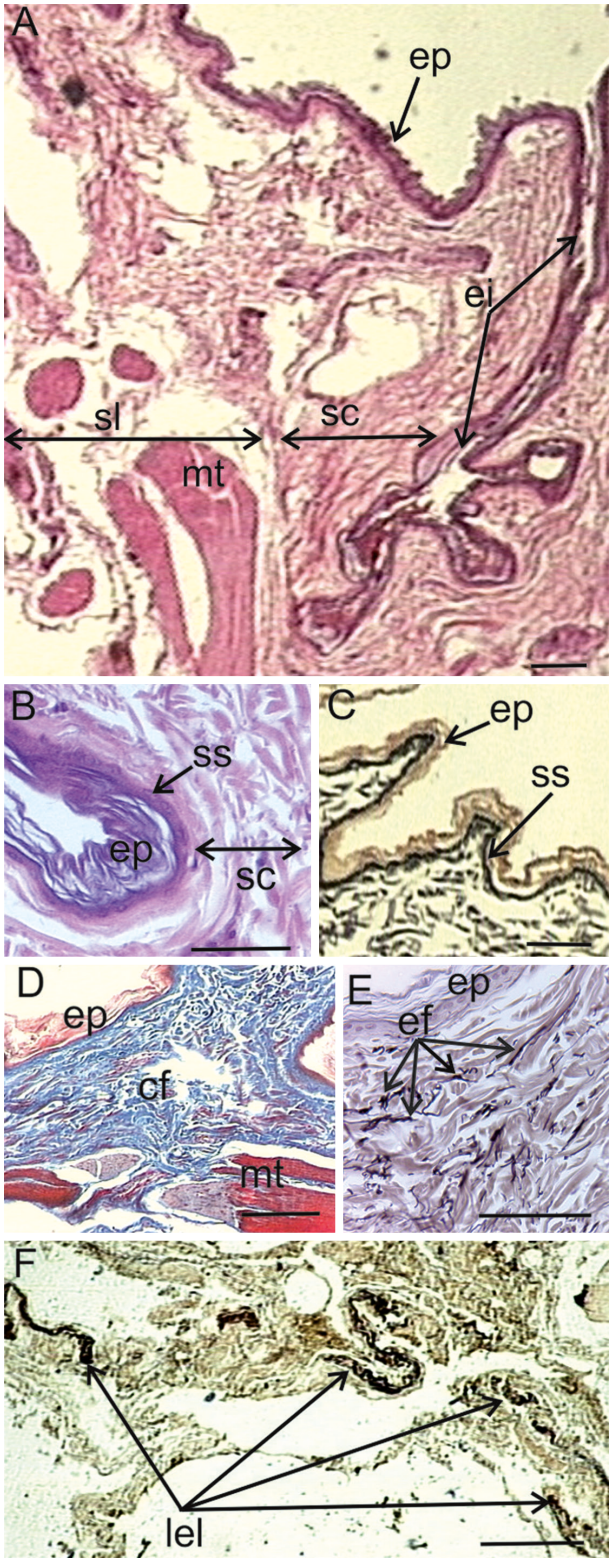
The skin and subcutaneous diverticula from a juvenile of *Chauna torquata* was obtained from the Jardín Zoológico y Botánico de La Plata (Buenos Aires, Argentina). The specimen was a healthy animal that was euthanized after suffering an accident, which only allowed an adequate sampling from the ventro-lateral region of the body. Three skin samples (1 × 1 cm), including the subcutaneous tissue, were taken. They were fixed in a 10% formaldehyde solution and processed for embedding in paraffin. Serial sections (3 µm) were stained either with Hematoxylin and Eosin for general histological description, Orcein for elastic fibers, Masson's trichrome for collagen fibers or Gomori for reticular fibers. The tissue structure was observed with an Olympus Ch30 light microscope. Photographs were taken with Leica Icc50 Hd camera mounted on Leica Dm 500 miscrocope. The anatomical terminology follows that of Baumel *et al.* (1993).

Results

The epidermis consisted of the three typical layers known for birds: the superficial stratum corneum, the stratum intermedium and the deep stratum basale. Hematoxylin and Eosin staining revealed a cornified, acellular stratum corneum (Fig. 1A). The stratum intermedium (Fig. 1A) consisted of one to three layers of cells whose nuclei tend to be flattened and are parallel to the skin surface as they approach the stratum corneum. The stratum basale (Fig. 1A) presented one layer of cylindrical cells with spherical nuclei.

The epidermis displayed deep, branching invaginations (Fig. 1B, 2A) that extend through the dermis, approaching in some cases, the subcutaneous diverticula.

The dermis showed the two typical layers described for birds: the stratum superficiale and the stratum profundum (Fig. 2 A,B,C). The former (Fig. 2 B,C) was thin, with loose connective tissue and with numerous reticular fibers (Fig. 2C) whereas the latter could be differentiated into two layers: the stratum compactum and the stratum laxum. The stratum compactum (Fig.1 A,B) consisted of an irregular dense connective tissue whereas the stratum laxum (Fig. 1A,F) presented loose connective tissue, and smooth muscle related to the feather follicles. In general terms the dermis was rich in collagen (Fig. 2D) and elastic fibers (Fig. 2E) and scarce in adipocites compared to other studied birds (Lucas & Stettenheim, 1972). The lamina elastica (Fig. 2F) highlighted for being discon-



tinuous unlike other birds (Lucas & Stettenheim, 1972; Weir & Lunam, 2004).

The subcutaneous diverticula, located deep to the dermis (Fig. 3A), consisted of a network of chambers (Fig. 3A,C) that were lined by a simple squamous epithelium and separated by thin, poorly vascularized walls of connective tissue (Fig. 3C) with elastic and reticular fibers (not shown in figures). Detached epithelial cells can be observed in the lumen of these chambers (Fig. 3C).

Discussion

The skin of *Chauna torquata* was similar to other birds (Lucas & Stettenheim, 1972; Hodges, 1974; Weir & Lunam, 2004) also, the histological structure of its subcutaneous diverticula was similar to that described for the air sacs (Hodges, 1974; Bacha & Bacha, 2000). However, the skin showed distinguishing features like the well-developed invaginations of the epidermis (as far as we know not previously described in other birds), the abundant elastic fibers in the dermis and the discontinuity of the lamina elastica. These skin features provide a great stretchability to the skin which, in turn, are related to the change of volume that may experience the subcutaneous diverticula, given that they can be inflated at will by the bird (Mayaud, 1950).

Screamers soar to great heights (Carboneras, 1992) and the inflated subcutaneous diverticula could contribute to lighten the body together with the extreme pneumaticity of the skeleton. Birds that fly at high altitudes have peculiarities in their respiratory system that allows sustained flight in a thin air (e.g.: tolerance to hypoxia, large lungs, haemoglobin with a higher oxygen affinity) (Farmer, 2006; Scott, 2011). Altought it is speculative, the presence of subcutaneous diverticula in screamers could be an anatomical feature associated with the high-altitude locomotion. It is necessary to conduct studies on further regions of skin and subcutaneous diverticula to reach to a more complete understanding of their morphological variations and potential functions in screamers. Furthermore, the subcutaneous diverticula are present in birds with different habits and habitats to those of the Southern screamer and with no direct phylogenetic

↑ **Fig. 2.** Structure of dermis: (**A**) Hematoxylin and Eosin stain showing the general structure of dermis, where it can be seen the sustratum compactum and the sustratum laxum, (**B**) High magnification showing the stratum superficiale and a part of the sustratum compactum, Hematoxylin and Eosin stain, (**C**) Gomori-stained section showing the reticular fibers of the stratum superficiale, (**D**) Masson trichrome-stained section showing collagen fibers in the dermis (**E**) and Orcein-stained section showing elastic fibers in the dermis, (**F**) Orcein-stained section of the final region from the stratum laxum showing the discontinuous lamina elastica, cf: collagen fibers, ef: elastic fibers, lel: lamina elastica, mt: muscular tissue, sc: sustratum compactum, sl: sustratum laxum, ss: sustratum superficiale. See the other abbreviations in the previous figures. Scale bar: 40 µm.

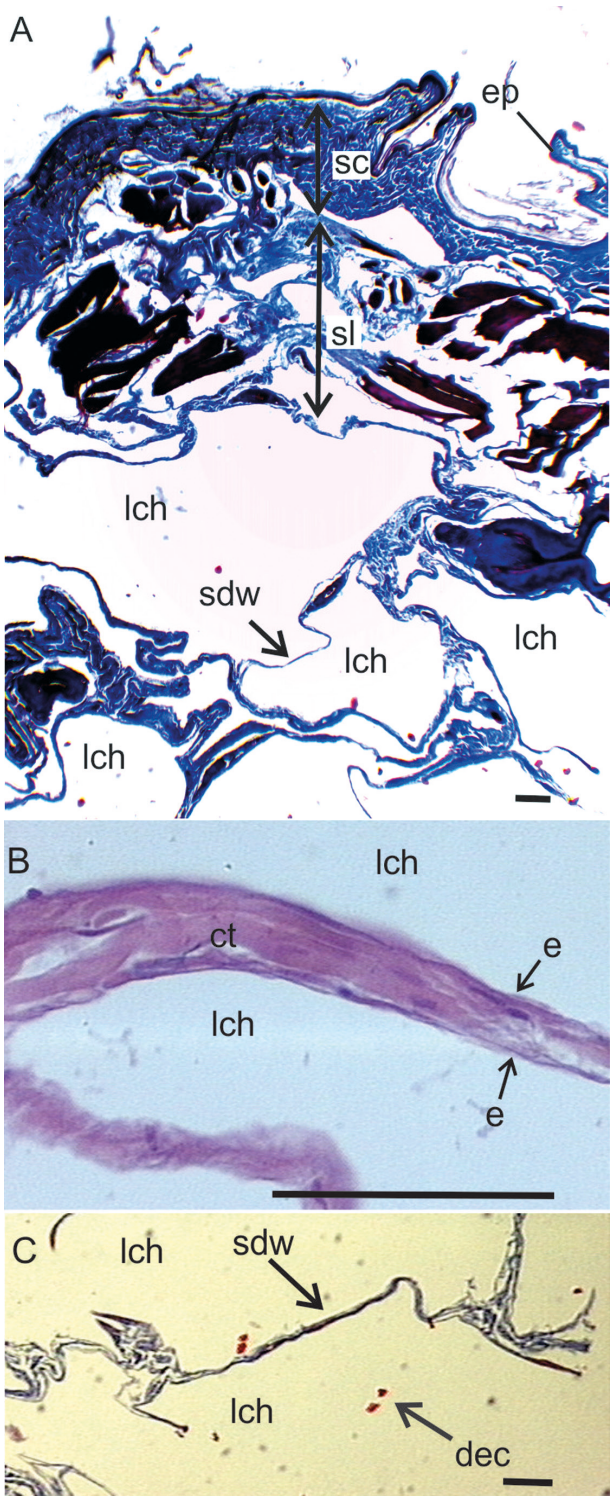


Fig. 3. Structure of subcutaneous diverticula: (**A**) general aspect of the subcutaneous diverticula and its relative position with respect to epidermis and dermis, Masson trichrome-stained section, (**B**) structure of the wall of a subcutaneous diverticulum, Hematoxylin and Eosin stain, (**C**) Masson trichrome-stained section, showing detached epitelial cells, ct: connective tissue, e: epithelium of subcutaneous diverticula wall, lch: lumen of the chamber, dec: detached epithelial cells, sdw: subcutaneous diverticula wall. See the other abbreviations in the previous figures. Scale bar: 40 µm.

relationship, such as pelicans (Order Pelecaniformes) (Richardson, 1939; Mayaud, 1950; Baumel *et al.*, 1993). Unfortunately, neither the skin morphology nor the possible role of the subcutaneous diverticula of these birds have been studied yet.

The integument of vertebrates includes the skin and associated structures (Wu *et al.*, 2004). In general, vertebrate skin is related to structures of ectomesodermal origin like feathers, hair, glands or scales (Chernova, 2009). It should be highlighted that the subcutaneous diverticula have an endodermal origin, forming with the epidermis an uncommon association. This association could be though as an important anatomical feature that helps the screamers to use such different ecological environment like great heights. More studies on this peculiar association will allow to test hypotheses of adaptive or phylogenetic constraint about its origin.

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