ADDITIONAL OBSERVATIONS ON THE STRUCTURE OF UNUSUAL FEATHER TIPS

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IN spite of their obvious importance in almost all phases of avian biology there are still some aspects of feathers which are poorly known structurally. Accordingly, interest in feather morphology persists among ornithologists (Portmann, 1963). One such area is the internal morphology of tipped elements which occur on feathers of widely diverse taxonomic groups of birds. Recently, for example, the relationship between pigment and feather tip structure has been described in the Cedar Waxwing (*Bombycilla cedrorum*) (Brush and Allen, 1963), and in the Scaled Cuckoo (*Lepidogrammus cumingi*) (Brush, 1965). These investigations have indicated the existence of at least two different structural arrangements involved in the formation of such tips. The first, as found in the waxwing, involves the expansion and flattening of the terminal portion of the rachis. In these structures, the structured medulla lies between unequal thicknesses of the surrounding amorphous cortex. The carotenoid pigment is deposited in the cortex. This uneven cover produces the shiny ventral and duller dorsal aspect characteristic of these tips. The second mechanism, as found in the cuckoo, involves the fusion of the rachis with a number of barbs and minor structural elements. This produces a flattened structure with an internally segmented appearance. Individual segments are compressed laterally and may fuse. There is a heavy pigment (melanin) concentration in the center of the tip. There are no external differences in the appearance of the surfaces in such tips.

The latter mechanism is more common than the former. Indeed, Chandler (1916) suggested that the structure in the waxwing may be unique among birds. It should also be noted that there is a weak correlation of one mechanism with melanin pigments and of the other with carotenoids. In no case described thus far is the functional aspect of these structures completely clear.

It was the objective of the study reported here to investigate further the structural and chemical nature of various unique feather tips not reported previously. Included in this investigation were feathers from the Curl-crested Araçari (*Pteroglossus beauharnaesii*) (family Ramphastidae), and several species of the genus *Rallus*.

METHODS AND RESULTS

Pigmentation.—The coloration of the tips in all feathers described in this study was due to melanin pigments. The techniques of bleaching with hydro-

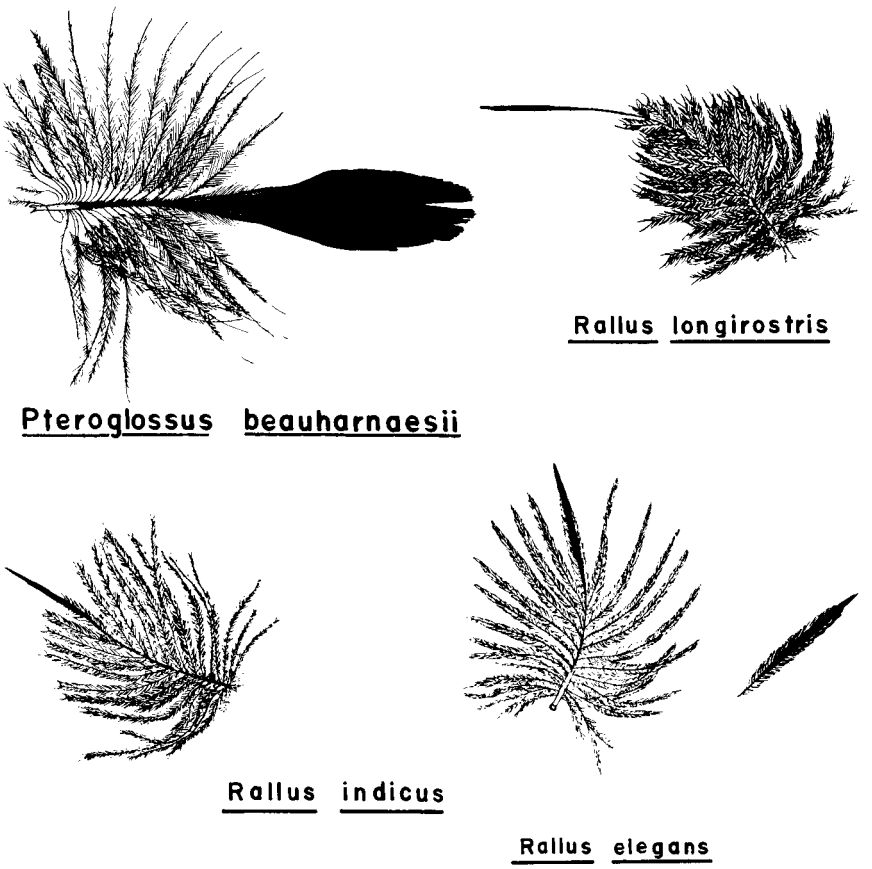

FIG. 1. Tipped feather from the crest of the Curl-crested Araçari (*Pteroglossus beauharnaesii*). Actual length, 20 mm.

Tipped feathers from several Rails. Lengths range from 7.2 mm (*R. elegans*) to 1.1 mm (*R. longirostris*).

gen peroxide or peracetic acid and reduction of ammonical silver nitrate were used for melanin analysis (Brush, 1965).

Structure.—Whole mounts of feathers were made with Canada balsam (Fig. 1).

Cross-sections were made by mounting tissues in methacrylate and sectioning with a glass knife. Several other techniques which included embedding and sectioning in high melting point paraffin (Dr. P. Stettenheim, pers. comm.), diethylene glycol distearate, or gelatin were tried, but met with less success.

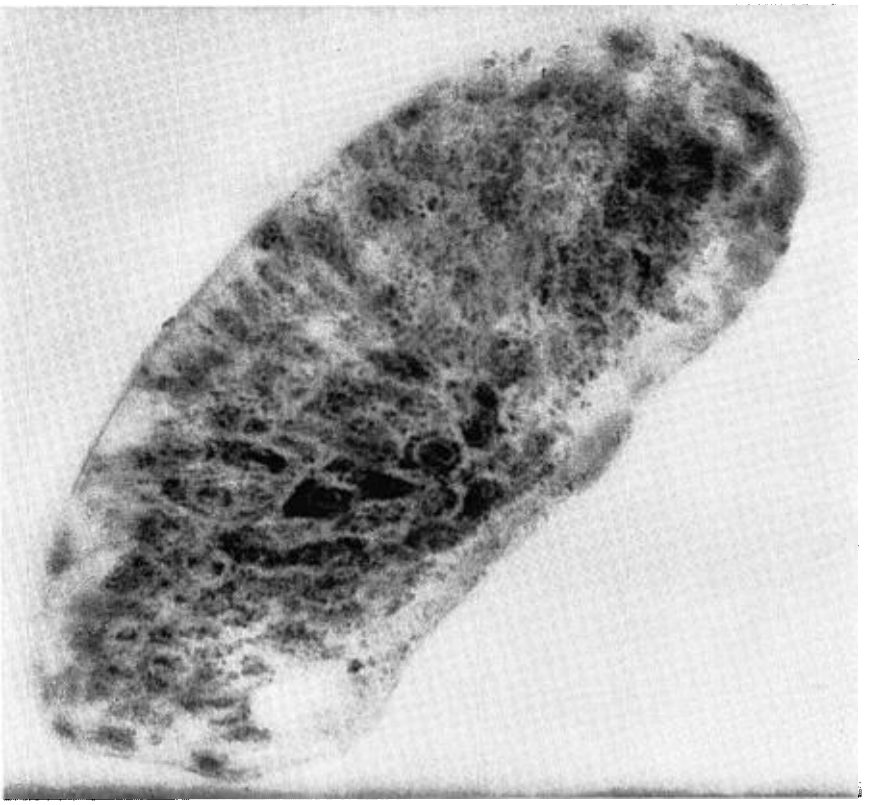

FIG. 2. Cross-section of feather tip from *R. indicus*. Note relatively unstructured cortical layer.

In cross-section the tips of the feathers from the crest of the Curl-crested Araçari appeared similar in morphology to that of the Scaled Cuckoo, in that the tip consisted of an internal medullary area which was heavily pigmented and which was surrounded by a relatively clear cortex. The highly keratinaceous cortex when seen in serial section supports the notion that it has developed from the fusion of several barbs or barb-like structures.

Cross-sections of the feather tips from members of the genus *Rallus* (*R. aquaticus*, *R. elegans*, and *R. longirostris*) presented a pattern quite different from that described above. Tips generally tended to be oval rather than flattened and the internal structure (Fig. 2) suggested that only the rachis was involved in the formation of the tip. The tips of the rail feathers lacked the regular, repetitive structural units characteristic of the *Pteroglossus* tip. The cuticle appeared unsegmented and the inner pulp contained pigment

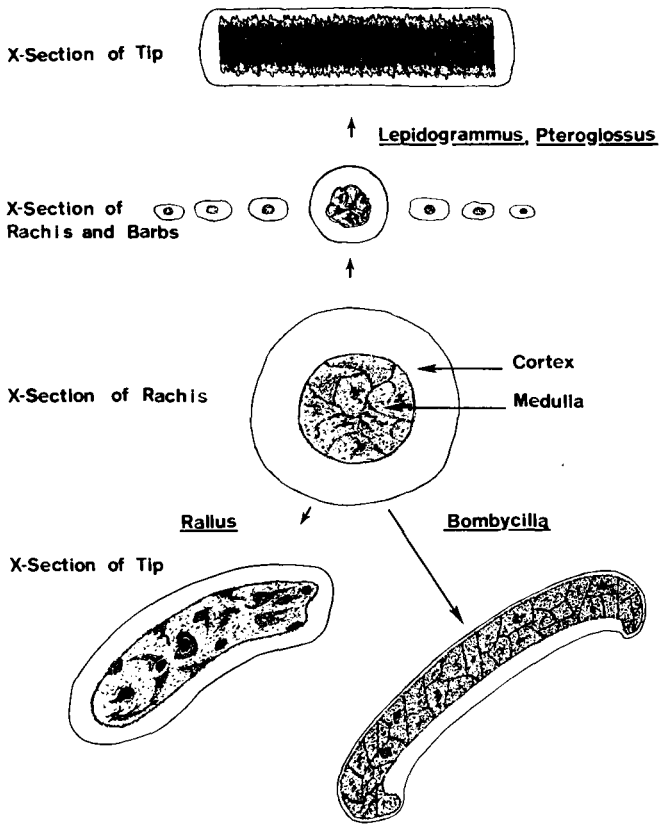

FIG. 3. Suggested relationships among various tipped feathers. The generalized structure of the rachis can be modified to produce tip structures of divergent morphology.

granules and various structural elements characteristic of the rachis. Generally, the tips of *Rallus* were considerably smaller than any of those investigated previously. Feathers similar to those in *Rallus* were also observed on the forehead of the Pied-billed Grebe (*Podilymbus podiceps*).

DISCUSSION

As was suggested earlier, at least two mechanisms may exist for the production of feather tips. Both types are found in widely divergent taxonomic groups and are therefore the result of convergent evolution within these group.

Bonhote (1912) observed that the external structure of the feather tip of the rails resembled those of the waxwing. There are, however, differences. The waxwing tip contains carotenoid rather than melanin pigments and it is

considerably more flattened than is the rail tip. Carotenoid pigments are deposited in the relatively clear, unstructured cortex while the melanin pigment of the rails is deposited in the medullular areas. In spite of these differences in the location and type of pigments it appears the basic internal structure is similar in both forms. Therefore the waxwing tip can no longer be considered an entirely unique structure.

The function of the feather tips described here is still somewhat obscure. Bonhote suggested that the tipped feathers on the head of the rails may serve a protective function in preventing the abrasion of the feathers as the bird moved through the underbrush. The small size and the fact that relatively few feathers actually have tips cast some doubt on this interpretation. However, the similarity of the size, structure, and location of the tipped feathers in the rails and the grebe may be a convergent response to similar selective pressures. The larger tips of the araçari and cuckoo may serve a signal function. However, they are dark and their visibility, and thus potential usefulness, in the animal's habitat is unknown. The absence of a satisfactory functional analysis of the tips in the waxwings has been discussed (Brush and Allen, 1962).

Regardless of differences in their internal structure and function, the feather tips presumably share a common origin (Fig. 3). The structural elements of the tips are derived ultimately from modifications of structural elements already present in feathers. The formation of feathers may be one of the most complex developmental processes in vertebrate skin as it involves the alignment of rows of cells which form the shaft, barbs, and barbules (Spearman, 1966). Additional studies on the control of development of these structures promise to be of interest.

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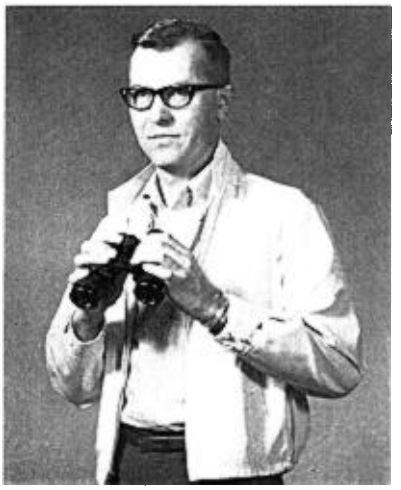

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