Chapter 2

FEATHER LOSS FROM CAPITAL TRACTS OF PAINTED STORKS RELATED TO GROWTH AND MATURITY : HISTOPHYSIOLOGICAL CHANGES AND LIPOID SECRETION IN THE INTEGUMENT

In the light of recent advances in integumentary research and interpretation of the term "secretion" in relation to vertebrate integument (Matoltsy, 1969; Lucas, 1968; 1970; Lucas and Stettenheim, 1972; Stettenheim, 1972: Jacob, 1978), the concept of avian integument as relatively inactive as far as secretory function is concerned, has become obsolete. Quay (1972) considers even the production of the hard structures like feathers as a "secretory" act of the avian integument. Lucas and Stettenheim (1972) who furnished evidences for secretion of lipoid substances by the avian epidermis considered the whole integument as a sebaceous gland. Formation of feathers involves an array of morphogenetic events (Lillie, 1940; Rawles, 1965; Lucas and Stettenheim, 1972; and Sengel, 1976) that follow a highly complex and orderly pattern of development; hence it deserves to be termed as "organogenesis" rather than "secretion". Thus the two major functions of avian integument that find morphological expressions are the production of cutaneous appendages (feathers and scales) and secretion of lipoid substance/s. Distribution of feathers on the skin is restricted to pterylae that are formed early

during development and their patterns are species specific. Sengel and Kieney (1967) have shown that in avaian embryos, feather germs could be experimentally induced to develop in areas which are normally destined to be apteric; thus demonstrating the potentials of the entire integument to give rise to feathers provided appropriate inducing factors are available. However, development of apteric zones from previously feathered areas as a normal feature during growth and development of certain birds has received little attention, despite the fact that morphological differences between natal and adult pterylosis in many birds are known. Stettenheim (1972) mentioned that the head of a young Sacred Ibis (Threskiornis aethiopica) is covered by down feathers, while in adults it becomes bare. In case of the Painted Stork (Ibis leucocephalus) natal downs are replaced successively by a generation of mesoptiles and then by the contour feathers. With growth and development of the birds, these countour feathers are progressively lost from the forehead and crown. In a two years old bird, the head becomes completely bare (Figs. 1 to 4). Knowledge of the type of feathers and degree of feathering in these regions have been employed by Desai (1975) as some of the criteria for approximate age determimation in the early life of these birds. Though general morphological account of plumage succession and feather loss in this case have been recorded, there is no information available on the histological and histochemical changes taking

EXPLANATION FOR FIGURES

Figs. 1 to 4 : Gross morphology of plumage succession in the capital region and formation of apterium in the Painted Storks.

Fig.1 Nestling (aged about 15 days)bearing mesoptiles.

Fig.2 Nestling wherein mesoptiles are being replaced by the grey contour (juvanal) feathers. Age about 45 days.

Fig.3. Subadult (1-year old) with partial feather loss. Note white definitive feathers in the coronal region.

Fig.4 Adult stork with fully formed capital apterium.


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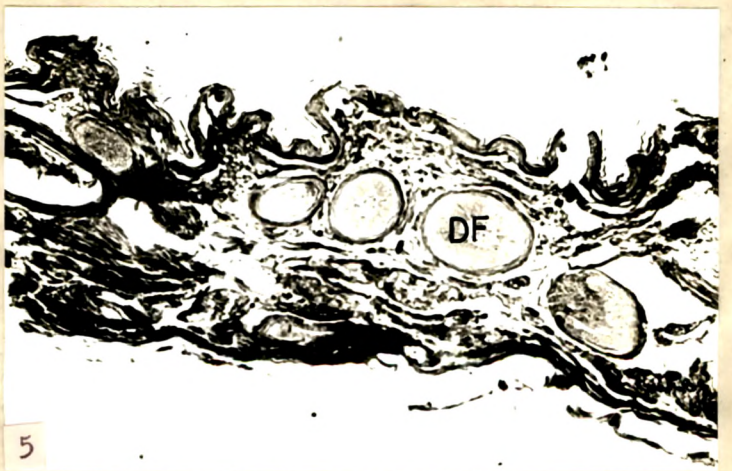
EXPLANATION FOR FIGURES

Fig.5 to 10 Histology of the integument.

Fig.5 Skin from capital region of a 5-day old nestling bearing natal down. Note developing mesoptiles in follicles. 42X.

Fig.6. Skin from capital tract of a 45 days old nestling. Note developing countour feathers. 76X.

Fig.7 V.S. of skin from capital region of one-year old stork. Note feather follicles and smooth muscles in the feathered region (FR) and changes in dermis in the secondarily apteric zone (AZ). 42X.



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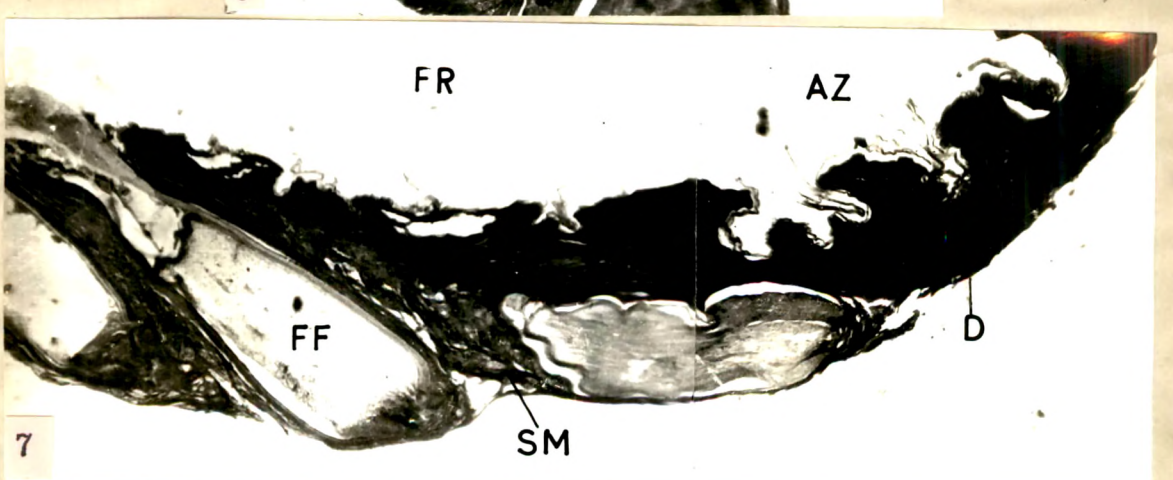

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place in the integument that accompany the transformation of the feather tracts into apteric zones. In the present chapter, observations on histological and, histochemical changes with regard to localization of lipids (neutral and acidic lipids) during various phases of capital apterium formation in Painted Stork are reported.

OBSERVATIONS

HISTOLOGY :

Nestlings with down feathers (About 10 days after hatching, Fig. 5).

Follicles with mesoptile feathers at various stages of development are seen. Interplumar epidermis is four to five cell layers thick. In the dermis, follicular muscle bundles are present, though, poorly developed. Besides, adipose tissue in the early stages of formation is discernible.

Juvanal with contour feathers (About 45 days after hatching, Fig. 6)

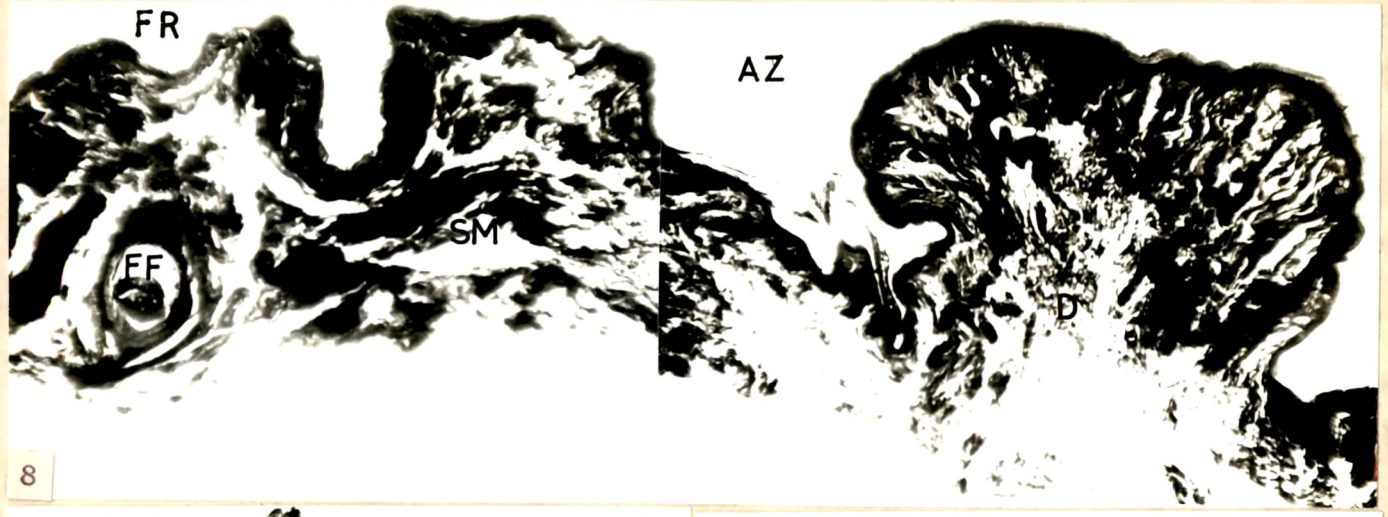
At this stage, feather follicles and juvanal feathers in various stages of development are discernible. Interplumar epidermis appears to be slightly thinner than that was seen in the previous stages. Dermis is well developed wherein well formed follicular muscles, fibrocytes, collagenous fibres and adipose tissue are observable.

Immature Stork (One year old, partially defeathered head, Fig. 7).

EXPLANATION FOR FIGURES

Fig.8 Section of skin from coronal region and adjoining cervical feather tracts (FR) of an adult stork. Note absence of feather follicles and smooth muscles in the dermis of apteric zone. 42X.

Fig.9 and 10 Enlarged parts of feathered region and apteric zone respectively at same magnification (76X). Note increased vascularity and epidermal stratification in the apteric zone.



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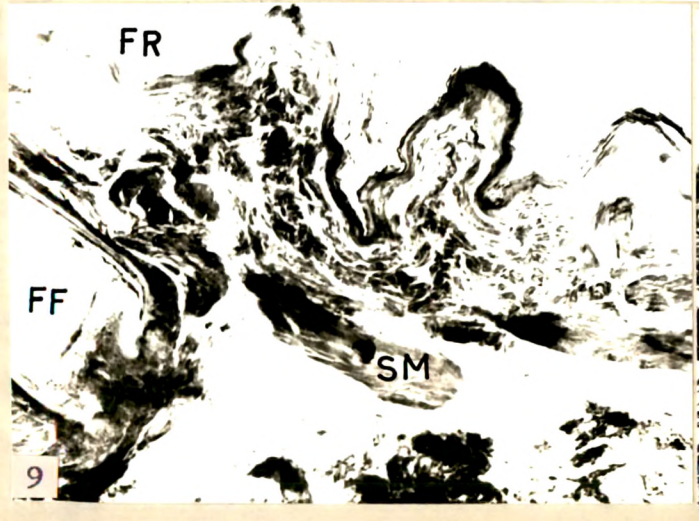

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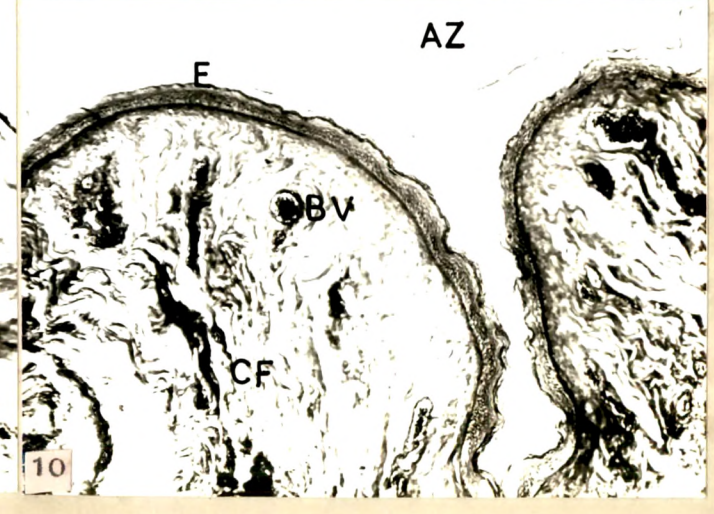

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While the feathered areas of skin exhibit the histological features similar to that described for the skin of juvanal birds, the areas which have secondarily become apteric, show marked difference in their histological features. Points of differences noticed in the defeathered areas are : the total absence of feather follicles with loss of major part of the follicular muscles and their typical pattern of arrangement. Feather follicles present near the junction in the feathered area have well developed follicular muscles disposed on their posterior and lateral aspects, while in the anterior aspect (in the apteric region) they are generally atrophied. In the dermis of the secondarily formed apteric zone, considerable increase in vascularity and reduction in the number of dermal fat cells are noted. Besides, extensive development of collagenous fibres is the most striking feature of the dermis wherein, a few remnants of muscle fibres and adipocytes are still detectable. Hyperplasia and stratification of epidermal cells resulted in the formation of a thick epidermis in the apteric region. Colour of the bare skin changes and becomes slightly yellowish due to the presence of carotinoid pigments in the epidermal cells.

Adult Stork (After the age of two years, Figs. 8, 9 and 10).

The bare skin on the head of adult Painted Stork shows considerable wrinkles. The epidermis in this part has become highly stratified. Compactness of the dermis, which is

characteristic of the feathered region, is lost in the apteric region and the collagen fibres are interspersed with lipid globules. Since the lipid gets removed during processing for histological preparations, these places appear as empty spaces in the dermis. Presence of lipoid globules is confirmed in fresh frozen sections with appropriate staining methods. High degree of vascularity is also noticed in the apteric regions where most of the vessels are confined to the superficial part of the dermis (i.e. subepidermal region). Few scattered muscle fibres (remnants of once well formed muscle bundles of the feather follicles of earlier stages) are observed. However, no remnants of feather follicles could be seen in the secondarily formed apteric zone.

Histochemical observations on distribution of lipids of Nestlings with protoptiles and mesoptiles :

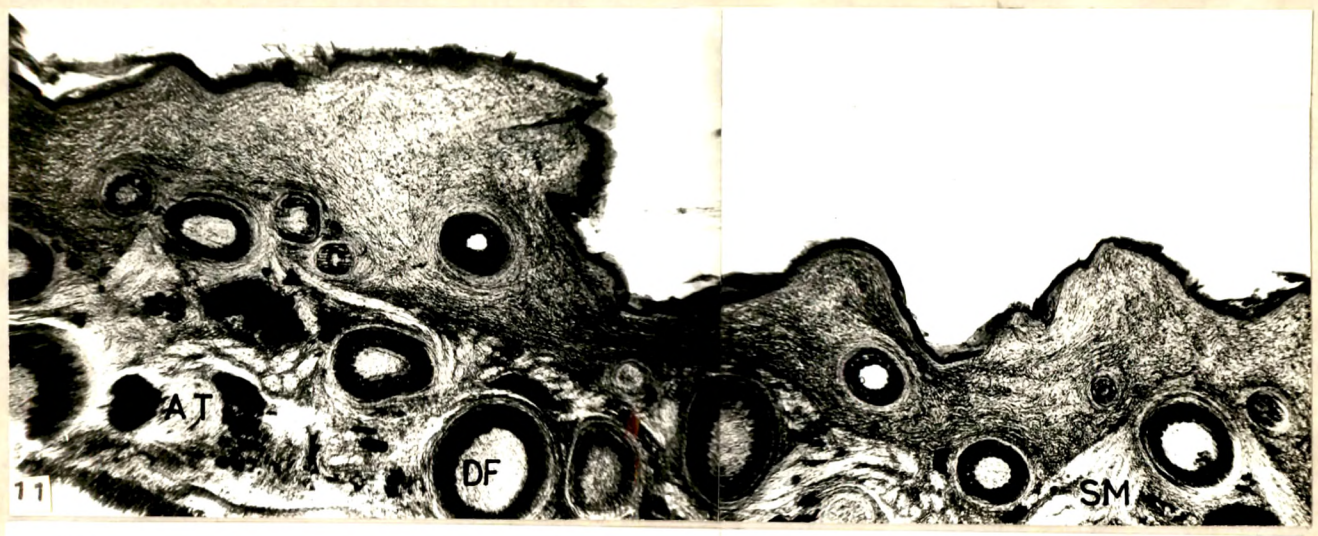
In the skin from the capital region of a 5 day old stork nestling, moderate amounts of neutral lipids are observed in the cells of stratum germinativum of the interplumar epidermis, pulp cells of the developing mesoptile feathers, and adipose tissue cells present in a scattered manner in the dermis. Other components of the dermis, including the smooth muscles had a low neutral lipid content. Acidic lipids, though low in concentration, were noticed in all the components of the skin including those of the developing feathers.

EXPLANATION FOR FIGURE

Figs. 11 to 17 Photomicrographs depicting distribution of neutral lipids in the integument.

Fig.11 Distribution of neutral lipids in the developing juvanal feathers and other skin components. 42X.

Fig.12 Skin from capital region of one year old stork. Note differences in distribution of lipids in the apteric zone and feathered regions. 42X.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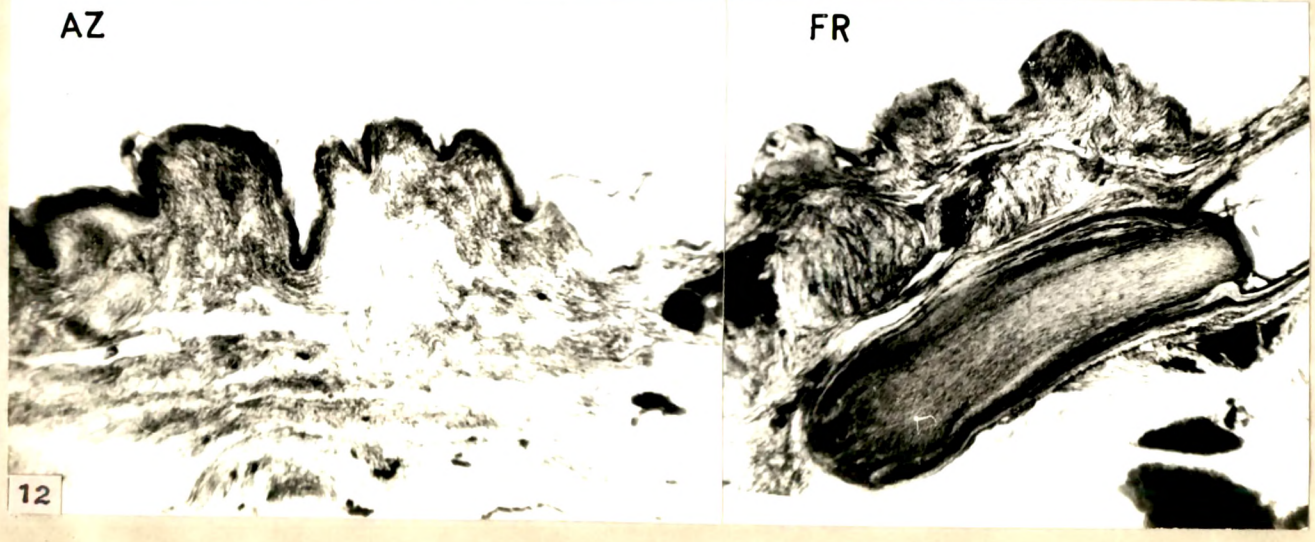
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In the nestlings bearing fully formed mesoptiles, with definitive feathers developing within their follicles (Fig.11), the skin components such as interplumar epidermis and adipose tissue registered an increased content of neutral lipids. Compared to these, dermal components and the developing definitive feathers showed only a moderate level of neutral lipid concentration. Acidic lipid content was fairly high in the epithelial cells of the developing feathers, smooth muscles of the follicles and cells of stratum germinativum of interplumar epidermis; but the fibrocytes showed only a low concentration of this metabolite. Cells of stratum corneum did not reveal presence of acidic lipids in them.

Juvanals with contour feathers (about 45 days after hatching) :

Moderate neutral lipid content was noticed in all parts of the interplumar epidermis, and pulp cells of the juvanal (contour) feathers, which are observed to be at different stages of development. However, cells of stratum corneum showed poor concentration of neutral lipids. Dermal components (except adipose tissue) exhibited quite a low concentration of neutral lipids. Acidic lipid content was high in all parts of developing feathers and stratum germinativum of interplumar epidermis. Muscle fibers and fibrocytes had moderate amount of acidic lipids.

Immature Stork (One year old, Fig. 12) :

The sharp demarcation observed at this stage, in the

EXPLANATION FOR FIGURE

Fig.13 Section of skin from adult stork. Note the abrupt change in lipid concentration from feathered areas (cervical tracts) to apteric zone and differences in lipid content of epidermis from the two regions. 30×.

Fig.14 A part of Fig.13 slightly enlarged to show details of the dermis. 42×.


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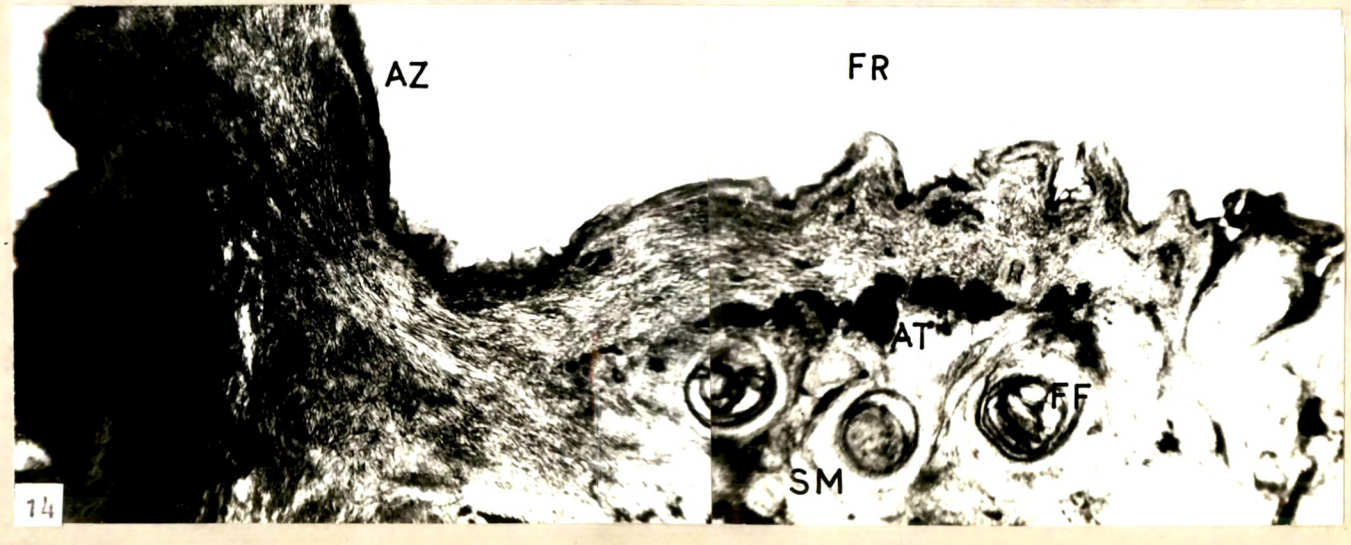
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histological features between feathered and the bare regions of the crown skin (secondarily formed apterium) was also evident in the distribution pattern of lipids in these regions. While neutral lipid in the feathered areas was low, the basal and cornified layers of the epidermis in the apteric region had very high content of neutral lipids (Fig. 15). However, in this region, the transitional epidermal layers had more acidic lipids. In the feathered region of the crown skin, follicular muscles and the resting feather germs in the dermis exhibited moderate amount of neutral lipids. Similarly, the dermal components in the apteric zone also showed moderate amount of neutral lipids.

Adult storks with completely bare head (After the age of 2 years, Figs. 13 and 14).

Striking differences in neutral lipid content and its distribution pattern between the feathered and apteric zones in the skin of occipital region of the adult storks were noticed (the apteric zone mentioned here corresponds to the previously feathered portion in the immature birds, and feathered region corresponds to the skin from the dorsal cervical region confluent with the capital apterium). Whereas the feathered region had only a low lipid content in the interplumar epidermis, feather follicles, and dermal components with the exception of adipose tissue, the apteric zone showed tremendous amount of neutral lipids in the epidermis and dermis,

EXPLANATION FOR FIGURES

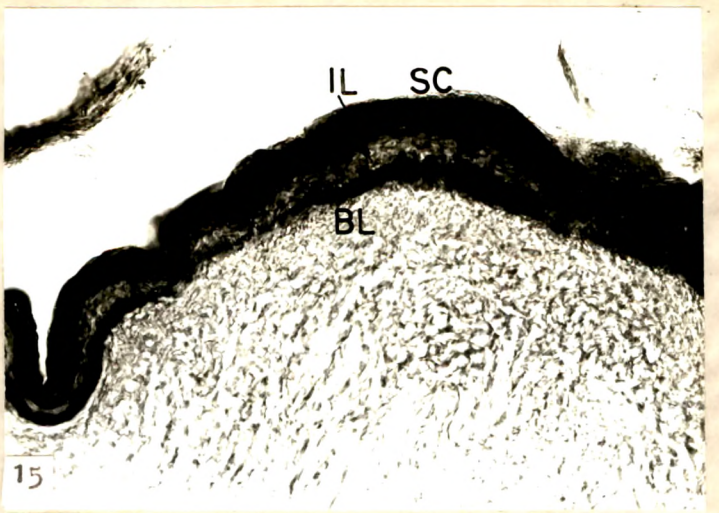
Fig.15 Photomicrograph showing neutral lipid distribution in secretory epidermis from a one-year old stork. 76X.

Fig.16 Photomicrograph of secretory epidermis of adult stork. Note distribution of lipids inthe layers of epidermis. 76X.

Fig.17 Photomicrograph of part of dermis from apterium of adult stork showing neutral lipid globules. 42X.

ABBREVIATIONS

AT- Adipose tissue; AZ- Apteric zone; BL- Basal layer; BV- Blood vessels; CF- Collagenous fibres; D- Dermis; DF- Developing feathers; E- Epidermis; FF- Feather follicle; FR- Feathered region, IL- Intermediary layer; SC- Stratum corneum; SM- Smooth muscle.



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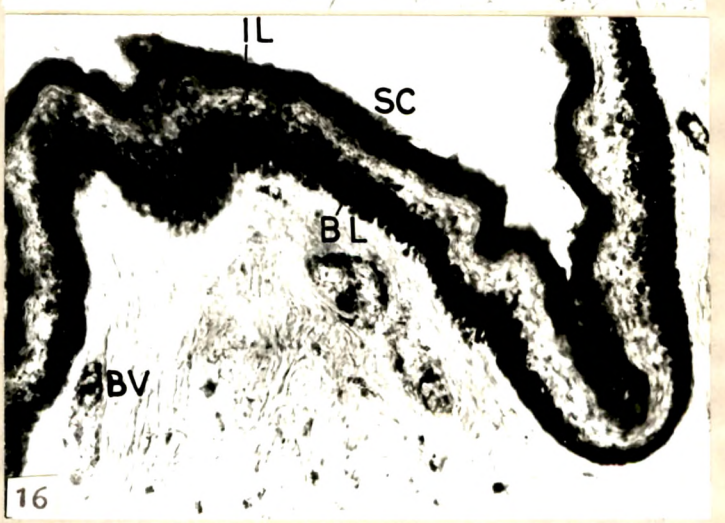

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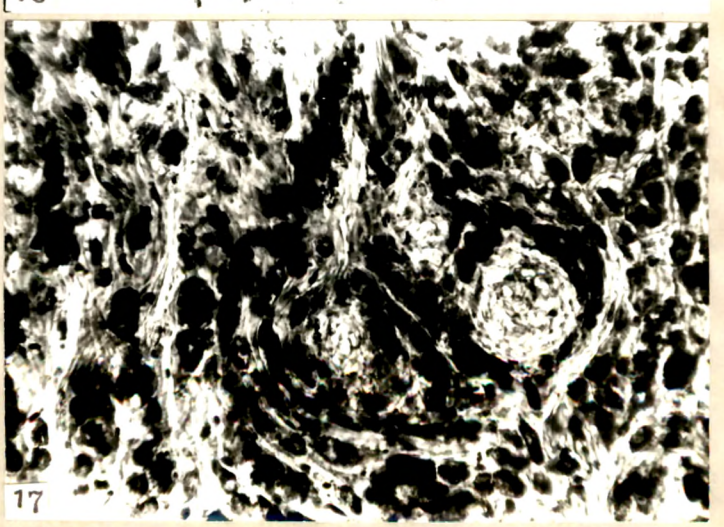

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inspite of the fact that there is a near total to complete loss of well defined adipose tissue, and follicular muscles and feather follicles (Figs. 16 and 17). Distribution pattern of acidic lipids was same as noticed in the crown skin of the immature storks - the transitional layer of epidermis being rich in acidic lipids and the cornified and basal layers rich in neutral lipids.

DISCUSSION

Histological and histochemical profiles of the skin from the crown region of Painted Storks during the post-hatching development and replacement of successive plumage generation conform to the general pattern known for all birds. Presence of lipids in avian integument and their significance in normal metabolic processes as also in development of integumentary derivatives are by now well established (Bell and Thathachari, 1963; Matoltsy, 1969; Lucas and Stettenheim, 1972; Shah and Menon, 1972).

Observations made on some of the histological and histochemical changes that accompany feather loss from the head (that is, from the frontal tract of the capital tracts), which in a one year old stork results in transformation of that region into an apteric zone, are quite noteworthy. The most striking histological features observed in the apteric region are, total absence of feather follicles, loss of follicular

muscles, almost complete loss of well defined dermal adipose tissue, acquisition of high degree of vascularity in the superficial parts (subepidermal) of the dermis and, increased stratification of the epidermis. Absence of feather follicles could be due to a complete degeneration of the feather germs resulting in their total loss in the secondary apteric zone, probably by a process of programmed cell death which is a normal feature of organogenesis during development in many species of animals (Saunders, 1966). The skin in the forehead region of Painted Storks loses even the follicular structures and the follicular muscles once it becomes bare. This is in contrast to the case of hairless mutant mice (Rigdon and Packchanian, 1974), where, the animals lose hair during post-natal period and become bare, nevertheless maintaining microscopic structures of the hair follicles in their so called nude skin. Stages of feather germ degeneration in the crown skin of the storks have not been observed which may perhaps be due to the fact that such degeneration occurs within a very short time either during the moulting period or just after it. Unfortunately, the material collected was not during either of these periods mentioned above. Detailed studies during these periods are needed to clarify this aspect of the problem. Watson (1963) has shown that normal moulting results with the old feathers being pushed out by the developing ones of the next generation. However, in the present case it would be of interest to know

as to how the old feathers get cast off without any new ones to push them off. The loss of most of the follicular muscles and their typical pattern of arrangement appear to be mainly due to extensive fibrosis of the smooth muscles. Similar changes are noted in the coronal tracts accompanying further loss of feathers from this region and consequent transformation into an apteric zone in the adult storks.

It is logical to visualise the concomitant changes in distribution pattern of lipids as an apparent adaptation to a secondarily acquired form and function of the previously feathered part of the capital integument. Tremendous increase in the dermal lipids noticed herein would enhance the flexibility of the secondarily formed fully exposed apteric skin which is subjected to considerable stretching during diverse and ritualised social displays that are used for communication by these aphonic adult storks. The varied distribution pattern of the two types of lipids, viz., neutral and acidic, in the different layers of the epidermis noticed herein reflects alterations in lipid metabolism associated with the functional maturation of the secretory epidermal cells. Such a phenomenon is probably of wide occurance in epithelial cells active in lipogenesis including that of chick embryo. Such epithelial cells have been aptly called as hybrid "keratinsebocytes" by Freinkel (1972). She noted that the functional maturation of such epithelial cells find expression in the production of

waxy esters and a decline in phospholipid content accompanying cornification.

Results of the present study clearly underscore the fact that adult avian integument bearing feather tracts has the potential of being transformed into apteric zones. Such a transformation brings about loss of one function i.e. production of feathers, and results in an enhancement of the other functional activity of the integument, viz., holocrine secretion. Thus, secretary function may not remain confined to the former interplumar skin, but may also be found in all other areas of skin where formerly feathers existed. It is also known that increase in integumentary lipid contents occurs during the formation of incubation patch in the House Sparrow (Selander and Yang, 1966). It is well known that temporary loss of feathers during formation of incubation patch in some birds involves hormonal activity (Bailey, 1952; Jones, 1971). From the facts at hand, it may be assumed that the permanent loss of feathers from the capital feather tracts of the adult Painted Storks and the exaggerated secretory activity of the secondarily formed apterium could be as a result of certain hormonal interplay. Comparatively higher secretory activity in the capital apterium noted in the adult storks (sexually mature) could be attributed to the breeding season whence the hormonal levels are bound to be high. The epidermal lipids, are known to serve as solvents for carotenoids (Vericak, 1938).

In this context it is feasible to assume that the high lipid content of the epidermis observed in the secondarily formed apteric region of the skin is also for providing a solvent medium for the carotenoid pigments which give bright coloura-tion to the skin. In fact, this part of the skin becomes increasingly brighter in coloration owing to such pigments during the breeding season. Besides, the high lipid content would also be helpful in maintaining the exposed apteric skin flexible and soft besides protecting it against desiccation and cracking. The epidermal lipids could be of considerable value in curtailing excess of evaporative water loss from the naked integument. The acquisition of hypervascularity in the sube-pidermal dermis region (subepidermal layer of dermis) can also be of thermoregulatory significance, besides its value in providing adequate amount of metabolites to the epidermis for lipogenesis.