Histological studies of whisker regeneration in the hooded rat

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INTRODUCTION

It has been shown that generations of rat vibrissae of normal or nearly normal length are produced after the removal of dermal papillae from vibrissa follicles and that even after removal of lengths of the lower end of the follicle ('root ends') regeneration of shorter than normal whiskers may occur. There seemed to be a certain maximal length, approximately one-third of the follicle, which could be removed before complete cessation of whisker production ensued (Oliver, 1966).

The destruction or inactivation of the dermal papilla, following the action of carcinogenic hydrocarbons and X-rays, has been said to be the cause of permanent epilation in pelage hair follicles (Wolbach, 1951; Geary, 1952). Nevertheless, there have been reports (e.g. Breedis, 1954; Billingham, 1958) that after the complete destruction or removal of populations of hair follicles in adult mammals, hair neogenesis may occur as it does normally during the seasonal growth of the deer antler. However, Straile (1959) has presented evidence that there is an inward migration of hair follicles from the wound margin and considers that this could account for the reappearance of hair follicles after injury.

This study was undertaken to determine whether dermal papillae are re-established in those follicles which regenerate vibrissae after the removal of dermal papillae and root ends and to investigate histologically the changes which take place during this process.

MATERIALS AND METHODS

Operations

All operations were performed on animals 2–3 months old from an inbred strain of Hooded rats. Anaesthesia was induced by the intraperitoneal injection of Nembutal (Abbott), 0.55 ml/100 g body weight. The whisker roots on the

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upper lip were exposed by making an incision below the most ventral row of whiskers and reflecting the whisker pad. The proximal (i.e. bulbular) ends of the whisker follicles were dissected free from connective tissue and one of two procedures was then performed.

A small incision was made in the centre of the bulb and the dermal papilla gently squeezed out as previously described (Oliver, 1966). Only follicles from which complete dermal papillae had been removed, consisting of the entire body and the apex (Plate 1, fig. B), were used for histological study.

From other follicles varying lengths of proximal whisker root ('root ends') were cut off. The length of follicle remaining, as judged by the lowest level of
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the ectoderm, was classified by histological examination according to the five regions delimited in Text-fig. 1. The regions 1, 2 and 3 are each approximately one-third of the distance between the base of the bulb and the fairly distinct junction, within the inferior enlargement, between vacuolated and non-vacuolated cells in the outer root sheath.

Some follicles were fixed and processed immediately after operation to determine whether papillary apex cells were present in the medullae of the cut shafts remaining in the follicles.

The major vibrissa follicles on the upper lip of the Hooded rat are widely spaced and constantly arranged in well-defined antero-posterior and ventro-dorsal rows allowing individual follicles to be identified with ease (Oliver, 1966). The position of the operated follicles on the lip was recorded and the whisker pad was stitched back in position. At no time did the animals have difficulty in drinking or feeding.

Animals were killed at various intervals after operation and sections of the operated follicles prepared.

Histology

The integrity of the dermal papillae which had been removed was verified by fixing them in formol saline and examining them, unstained, under a dissecting microscope.

Whole upper lips and individual vertical rows, obtained for the study of normal follicle structure, were fixed in formol saline or Bouin's fixative. Formol saline was also used for fixing the majority of operated follicles removed; Bouin's fixative was used for the remainder.

Serial sections 8 μ in thickness were stained with either Ehrlich's haematoxylin and eosin, or a combination of Weigert's haematoxylin, alcian blue and Curtis's Ponceau S.

RESULTS

Removal of dermal papillae

Three follicles were removed and fixed 3 h after operation. At this stage the dermal papilla cavity was narrowed and some of the proximal part of the matrix was extruded through the cut in the proximal end of the capsule where a small blood clot had formed. The more distal matrix was undisturbed and contained germinal cells in mitosis (Plate 1, fig. C).

2 days. By now the typical bulb organization had been lost and no traces of the original dermal papilla cavity were present (Plate 1, fig. D). The outer root sheath was present as a rod or column of cells and was fairly basophilic proximally; it contained many cells in division, and extended below the cut in the capsule and through the blood clot. Traces of keratinizing cells were present within the projecting part of the ectoderm and a strand of these cells extended up the outer root sheath rod to ensheath the proximal end of the previously growing keratinized vibrissa shaft, which was now situated some distance from
the base of the rod. The glassy membrane was very thick and present down to the level of the cut across the capsule. The mesenchymal layer was also thickened proximally and had taken up the alcian blue stain within the region of the cut edge of the capsule.

4 days. The vibrissa shafts were lost from the follicles, presumably because no club attachments were formed. The ectodermal rod was rounded proximally and extended below the termination of the glassy membrane; mitoses were present only in the distinctly basophilic region of the ectoderm, which was restricted to the lower part of the rod (Plate 1, fig. E). A partially keratinized strand of cells, containing large 'ghost'-type nuclei, extended upwards from the most proximal aspect of the ectodermal rod. Dermal tissue confluent with the mesenchymal layer was present between the lower edge of the ectoderm and the fibrous encapsulation forming at the bottom of the follicle. This dermal tissue was stained blue-green both immediately above and immediately below the level of the abrupt ending of the glassy membrane, but not in the more densely nucleated tissue around the end of the ectoderm. Several mitoses were present in the blue-green-stained dermal tissue, associated in most cases with invading capillaries. In one of the follicles, dermal tissue, apparently headed by capillaries, was invading the ectodermal rod at a level just below the termination of the glassy membrane.

8 days. A regenerating dermal papilla was present in both of the follicles examined at this time; in one instance as a small dermal indentation in the base of the ectoderm (Plate 1, fig. F) and in the other as a larger indentation. The most proximal level of the ectoderm was situated some distance above the termination of the glassy membrane and dermal cells were apparently passing through the substance of this region of the glassy membrane into the developing dermal papillae. Above the papillae the ectoderm was strongly basophilic and becoming organized into the matrix and hair cone. A strand of partially keratinized cells, identical histologically with the outer root sheath cells encountered in the neck of these and normal follicles, was present in both follicles.

10 days. Both follicles examined contained dermal papillae (Plate 1, fig. G) and were growing fine non-medullated whiskers. In each follicle the matrix was differentiated into its respective layers, the papilla had a small apical projection and the basal stalk was becoming constricted; the capsule was virtually re-established proximally.

Subsequent stages. After 12 days and more the bulbular region of the follicle continued to increase in size; capillaries were present in the dermal papilla itself by 16 days and after 21 days (Plate 1, fig. H) the growing fibres reached 6 mm above skin level. One of the follicles after 21 days contained a dermal papilla with two apical spikes, and in both follicles blood cells were present at the papilla apex. By 24 days a medullated fibre was being produced; the dermal papilla was comparatively large and contained a dense population of nuclei and the definitive basal stalk was finally established.
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Three follicles from which dermal papillae had been removed for the long-term assessment of the effects of this operation were also sectioned. Two of these were fixed 142 days after operation; the dermal papilla in one appeared normal but in the other follicle the apex of the papilla was divided into two. In the third follicle, fixed 118 days after operation, two dermal papillae with a common basal region were present. This follicle had produced generations of whiskers with a single tip and a doubled base.

Removal of root ends

Fourteen follicles were fixed immediately after the removal of root ends.

While it is possible that cells of the dermal papilla apex were present in the medullae of the cut shafts in two or three of the follicles which were in an advanced stage of anagen, none could be detected in the remainder. The cytoplasm of the cells which may have been confluent with the papilla apex stained red and did not take up the alcian-blue stain as did the dermal papillae of pelage hairs in the same sections.

4 days. Root ends had been removed in region 2 in one follicle and within region 3 in the other four follicles examined after this time. The cut shafts of the growing whiskers present at operation were lost from three of these five follicles. The outer root sheath cells at the most proximal end of all the follicles had coalesced (Plate 2, fig. J), while in two of the follicles from which the cut shaft had been lost the outer root sheath was present as a rod or column of cells up to a level just below the sebaceous gland. A distinct glassy membrane was present around the outer root sheath, but not over the cut, proximal surface in any follicle.

8 days. Root ends had been removed within region 2 in two follicles, region 3 in another and in region 4 in a further two of the five follicles examined. The cut vibrissa shafts had been lost from all but two follicles, in one of which the shaft had dropped through beyond the cut across the capsule. With the exception of the latter follicle the outer root sheath cells had coalesced proximally and there was an aggregation of dermal cells adjacent to the proximal end of one of the outer root sheath rods and to a lesser extent in another follicle, at which level the outer root sheath cells were pronouncedly basophilic (Plate 2, fig. K). A basement membrane did not appear to be present at the most proximal aspect of the outer root sheath except in one of the follicles from which the root end had been removed within region 4.

The cut ends of all the follicles were sealed off by a fibroblastic layer of cells, with some possible fibroblast migration into the lower end of the follicles. Capillaries were prominent at the proximal end of all the follicles.

12 days. Root ends had been removed from within region 2 in three follicles and region 3 in a further two follicles. The cut shafts had been lost from four of these follicles, but in the fifth (removal within region 2) both the club and cut shaft had dropped through beyond the level of the cut across the capsule. Of the
other two follicles in which root ends had been removed within region 2, one contained a well-formed dermal papilla and hair cone, with many mitoses in the developing basophilic matrix (Plate 2, fig. M) while the outer root sheath of the second follicle was present as a sac, the most proximal aspect of which was situated at about the level of the inferior enlargement.

The outer root sheath rod was rounded proximally in the fourth follicle, and in the fifth a small densely basophilic protuberance was present with a distinct aggregation of dermal cells beneath it. In both follicles mitoses were present in the proximal region of the outer root sheath over which a basement membrane was still not apparent.

16 days. By 16 days, and after, the cut vibrissa shafts had been lost from all of the follicles. Root ends had been removed from within region 2 in three of the five follicles examined. In two of these follicles a dermal papilla was present as a small indentation in the centre of the proximal end of the outer root sheath rod; the ectodermal cells around these papillae were distinctly basophilic and contained cells in division (Plate 2, fig. L). The outer root sheath rods contained

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**PLATE 1**

Fig. A. Vertical section of an unoperated early anagen vibrissa follicle (compare Text-fig. 1). Note that at this stage there is no apex to the dermal papilla nor is the growing whisker medullated. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 25.

Fig. B. A removed dermal papilla. Note the intact 'body' and long apex; unstained. × 90.

Figs. C–H. Stages in regeneration of dermal papillae, after the removal of dermal papillae.

Fig. C. Sagittal section of the proximal end of a follicle fixed 3 h after removal of the dermal papilla. No traces of the dermal papilla are present. Cracks in the matrix occurred during histological preparation. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 70.

Fig. D. Slightly oblique section through the proximal end of a follicle 2 days after operation. The dermal papilla cavity is no longer present; the typical matrix organization is lost and the proximal mesenchymal layer and glassy membrane are thickened. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 85.

Fig. E. Sagittal section of the proximal end of a follicle 4 days after operation. The ectoderm is rounded proximally; a partially keratinized strand of cells is present on the left. Dermal tissue is apparently invading the ectoderm (arrows) just below the proximal termination of the glassy membrane. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 125.

Fig. F. Sagittal section of the proximal end of a follicle 8 days after operation. The developing dermal papilla is present as a small indentation. The glassy membrane extends below the most proximal level of the ectoderm (arrow). A strand of keratinizing cells, identical histologically with high level outer root sheath cells, is also present in the right-hand side of the follicle. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 75.

Fig. G. Slightly oblique section of the proximal end of a follicle 10 days after operation. The dermal papilla has a small apical projection: the matrix is differentiated into its respective layers. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 80.

Fig. H. Vertical section of the proximal end of a follicle 21 days after operation. The basal stalk of the dermal papilla is forming. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 95.
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a central core of densely staining cells which may have represented a future hair cone. The glassy membrane extended below the most proximal level of the outer root sheath (Plate 2, fig. L). In the other follicle from which the root end had been removed within region 2, and in the follicle from which the root end had been removed within region 3, a regenerated dermal papilla, matrix and growing whisker shaft were present (Plate 2, figs. N and P).

The fifth follicle had had its root end removed within the region of the cavernous sinus (region 4) and demonstrated a complete glassy membrane around the outer root sheath. There was no indication of papilla regeneration;

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**Plate 2**


Fig. J. Median section of the proximal end of a follicle 4 days after removal of the root end from within region 2. The glassy membrane is considerably thickened and the outer root sheath cells are coalescing to form a rod; the cut edge of the capsule is indicated. Ehrlich's haematoxylin and eosin. × 130.

Fig. K. Vertical section of the proximal end of a follicle 8 days after operation (removal within region 2). The ectoderm has become a solid rod with a pronounced basophilic region proximally. The cut edge of the capsule is indicated. Ehrlich's haematoxylin and eosin. × 60.

Fig. L. Vertical section of the proximal end of a follicle 16 days after operation (removal within region 2). The regenerating dermal papilla is present as a small indentation in the centre of the proximal end of the outer root sheath rod. The glassy membrane extends below the ectoderm (arrows). Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 90.

Fig. M. Vertical section of the proximal end of a follicle 12 days after operation (removal within region 2). The dermal papilla is clearly confluent with the mesenchymal layer; the matrix is becoming differentiated. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 145.

Fig. N. Vertical section of the proximal end of a follicle 16 days after operation (removal within region 3). A non-medullated whisker is being produced. The proximal aspect of the ring sinus can be seen at the top right. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 90.

Fig. P. Vertical section of the proximal region of a follicle 16 days after operation (removal within region 2). The regenerated dermal papilla has no apical projection and the growing whisker is non-medullated. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 50.

Fig. Q. Vertical section of the proximal end of a follicle 392 days after removal of the root end from within region 2. This follicle had produced several generations of whiskers after operation although at biopsy a growing whisker was not present. There is no discrete dermal papilla. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 80.

Fig. R. Vertical section of the proximal end of a persisting follicle remnant 392 days after removal of the root end from within region 3. No whiskers were produced from this follicle after operation. A dermal papilla is not present; the inclusion within the proximal region of the ectodermal rod resembles the glassy membrane in texture. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 90.

Fig. S. Vertical section of the persisting remnant of a follicle 392 days after removal of the root end from within region 4. Weigert's haematoxylin, alcian blue and Curtis's Ponceau S. × 40.
it closely resembled the follicle shown in Plate 2, fig. S, which had produced no whiskers 392 days after the removal of the root end at a similar level.

20 days. Root ends had been removed from within region 2 in one follicle, which now contained a regenerating dermal papilla and was producing a whisker, and within region 3 in another four. Two of the latter follicles also contained a regenerating dermal papilla and growing whiskers. A small dermal papilla rudiment was present in another of these follicles. The adjacent outer root sheath was basophilic and contained cells in mitosis. In the fifth follicle the outer root sheath was present as a rod of vacuolated cells below the inferior enlargement, widening proximally with a slight indentation in the base. No pronounced cytoplasmic basophilia was present in the outer root sheath nor was the aggregation of dermal cells at the base pronounced.

30 days. The root end had been removed from within the lower extent of region 2 in one of the follicles which now contained a non-medullated growing whisker 12 mm in length above skin level. The regenerated dermal papilla was quite large and contained capillaries; the base of the matrix was at the same level as the original cut through the capsule. Three other follicles had had root ends removed from within region 3; the outer root sheath was present as a rod in the lower half of the lengths of follicle left after operation and the most proximal level of the ectoderm was situated above the cut across the capsule. In two of these there was an aggregation of dermal cells two to three cells deep, which had taken up the alcian-blue stain, present over the proximal surface of the outer root sheath rod. In one follicle the proximal cells of the outer root sheath were basophilic but there were no mitoses present in the outer root sheath cells in either follicle. In the fourth follicle there was no proximal aggregation of dermal cells and no marked basophilia or mitoses in the outer root sheath.

392 days. Five follicles were also fixed and examined histologically 392 days after removal of root ends, during which time three of the follicles had produced generations of post-operative whiskers; there had been no evidence of whisker growth from the other two follicles. Sections of the root ends removed from all five follicles had demonstrated not only that the entire dermal papilla, including the apical region, had been removed in each instance but that the three follicles which had produced generations of post-operative whiskers had had their root ends removed from within the lower third of the original follicle length. Histological examination of the follicles showed that the original level of cut across the capsule was still clearly discernible, and confirmed the level of root-end removal estimated by examination of the removed root ends.

Root ends had been removed from within region 2 in two of those follicles which had subsequently produced whiskers 35% and 30% of the length normally produced by follicles occupying the same position on the upper lip. The first of these was in late anagen at biopsy and was producing a non-medullated pigmented whisker. The dermal papilla was quite large and non-attenuated and contained capillaries. Since the bulb was arranged at right angles to the long
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axis of the follicle, it would appear that the follicle had lengthened slightly after operation but was contained by the fibrous encapsulation which had formed at the level of the original cut across the capsule. The second of these two follicles did not contain a growing whisker. There was no discrete dermal papilla but a layer of dermal cells, two to three cells deep and confluent with the mesenchymal layer, was present over the rounded proximal end of the outer root sheath rod (Plate 2, fig. Q).

The third follicle which had produced whiskers had had the root end removed from within region 3; it had produced generations of whiskers 24 % of the normal length, and was in late anagen at biopsy. A non-medullated, pigmented fibre was being produced. The dermal papilla was small, non-attenuated, and contained capillaries. The base of the matrix was present just below the original level of cut across the capsule; otherwise the follicle closely resembled that shown in Plate 2, fig. N.

Of the two follicles which had produced no whiskers after operation, the root ends had been removed from within region 3 in one and within region 4 in the other. The former follicle had persisted even though a dermal papilla had not regenerated, although within the proximal region of the outer root sheath there was a layered inclusion which closely resembled the glassy membrane in texture. Around this body the ectoderm was basophilic (Plate 2, fig. R). The proximal level of the ectodermal rod was present above the original cut across the capsule. In the latter, the follicle remnant had also persisted and there was no indication of papilla regeneration. The follicle cavity was present down to the level of the sebaceous gland (Plate 2, fig. S).

DISCUSSION

The results confirm the previous observation, based on examination of the root ends removed, that regeneration of whiskers occurs only in those follicles in which not more than the lower one-third of the follicle is removed (that is, from a level in the lower extent of region 3 and below; Text-fig. 1).

Whiskers produced after the removal of root ends are shorter than normal and there is little increase in length over successive growth cycles (Oliver, 1966); this is probably related to the fact that, after an initial small distal movement, there is little or no lengthening of the ectodermal component of the follicle after the removal of the root end. (It should be borne in mind that the vibrissa follicle, unlike pelage hair follicles, is normally fairly static in length during the growth cycles; there is very little shortening at catagen.) Regeneration, as after removal of the dermal papilla alone, occurs by tissue reorganization at, or just above, the level of incision at operation.

The various stages in the regeneration of dermal papillae which have been observed are very similar to those described by Davidson & Hardy (1952) for the ontogenetic development of papillae in the vibrissae of the mouse.
Montagna & Chase (1956) have shown that, after X-irradiation of the scalp at certain doses, as one result of which the matrix of each hair follicle is destroyed, a complete hair follicle is formed from the shortened cord of outer root sheath cells with which the dermal papilla remains in contact. On these grounds Montagna (1962) has stated that ‘The seed, or the germinative source of each generation of hair follicles, must reside in the outer root sheath and not in the bulb.’ Since vibrissae are regenerated after surgical removal of the bulbular region of the follicle, containing both the matrix and the dermal papilla, the follicular tissues distal to the bulb, including the outer root sheath, are clearly of importance. However, the relative importance of the outer root sheath and the mesenchymal layer in the regeneration process is difficult to assess. Wang (1943) has demonstrated that in feather follicles only the basal half of the follicular epidermis is capable of forming feathers under the inductive influence of implanted dermal papillae. Whether the cells of the outer root sheath above the level of non-regeneration are, similarly, capable of forming vibrissae under the inductive influence of implanted dermal papillae has yet to be shown. This may be possible since Cohen (1965) suggests that vibrissa dermal papillae implanted under ear skin may become invested by ear epidermis and produce hairs of the local kind.

Some aspects of the dermal papilla and its role in the production of hairs and feathers and in follicle maintenance may now be considered in relation to the present findings.

In feather follicles, although dermal papillae apparently do not regenerate after the removal of the ‘whole papilla’ (the dermal papilla and its ectodermal investment) from the base of the follicle, ‘whole papillae’ transplanted under the skin can regenerate new follicles and generations of feathers (Lillie & Wang, 1941, 1944). For these reasons the dermal papilla of feather follicles is regarded as a discrete and permanent entity. Similarly, Cohen (1961) has suggested that the dermal papilla in vibrissa follicles is also a discrete and permanent entity since transplanted root ends and ‘whole papillae’ are capable of producing generations of short whiskers ectopically.

The present work has shown, however, that although the dermal papillae in rat vibrissae normally persist throughout the growth cycles (also observed by Dry (1926) in mouse vibrissae) they can be regenerated after complete removal of the original dermal papilla. Of some interest here is the follicle which had produced several generations of vibrissae after removal of the root end yet did not contain a discrete dermal papilla at biopsy. However, no growing fibre was present at this time. Almost certainly this follicle was in telogen. Previous observations on the growth of whiskers after removal of root ends indicated that some of these follicles had a resting phase during the growth cycle since club whiskers were often present in the follicles for long periods of time before the appearance of the next generation of whiskers. Whisker follicles apparently do not naturally have a resting phase and the dermal
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papilla is always at least partly contained by the ectodermal component of the follicle.

Many workers have considered that the dermal papilla in hair follicles is similar in nature to the dermal papilla of the feather follicle. Billingham & Silvers (1963) have referred to the ‘absolutely indispensable’ presence of the dermal papilla in the regeneration of complete new epidermal appendages after the exposure of hair follicles to various types of injury. However, the possibility of regeneration of the dermal papilla after its surgical removal does not appear to have been considered. It is now generally agreed (e.g. Wolbach, 1951; Chase, 1955; Montagna & Van Scott, 1958) that the dermal papilla persists throughout the hair growth cycles, although Dry (1926) believed that a new dermal papilla was formed before each anagen in mouse pelage hairs. It would therefore be of considerable interest to see if hair follicles, like vibrissae, can regenerate dermal papillae and fibres after removal of the lower part of the follicles including the dermal papillae. This is particularly important because, although destruction of the dermal papilla has been said to be the important factor in permanent epilation arising from various types of injury (e.g. Wolbach, 1951; Geary, 1952), this has often been deduced from the results of experimental procedures which do not selectively destroy or remove the dermal papilla alone but also destroy other follicle components and even, in some cases, the whole follicle.

The histological evidence strongly suggests that cells from the mesenchymal layer, which is normally confluent with the dermal papilla, at least contribute to, and possibly become, the new dermal papillae in vibrissae. These cells appear to move into the site vacated by the distally moving ectoderm, the future site of the new dermal papilla, and were often seen apparently in process of passing through the substance of the ‘trailing’ glassy membrane. It is therefore possible that the equivalent structure in hair follicles, the dermal sheath, may be capable of contributing to the dermal papilla and thus help to maintain it throughout the growth cycles.

The present results re-emphasize that a dermal papilla is always present in follicles producing fibres and that no fibre production occurs unless dermal papillae have first regenerated. Although apparently normal-sized dermal papillae regenerated after the removal of dermal papillae, associated with the production of whiskers of normal length, smaller than normal papillae regenerated after the removal of root ends, associated with the production of shorter than normal whiskers.

It seems likely that the dermal papilla must be present to maintain fibre production after it has been initiated since, after removal of the dermal papilla alone, growth of the whisker currently present at operation ceased and it was lost from the follicle. It is, however, possible that cessation of growth may have been caused by the trauma of operation. In these follicles much of the matrix which would otherwise have become shaft and inner root sheath formed, instead,
a strand of keratinizing cells identical histologically with the outer root sheath cells present in the neck of the follicle.

However, the presence of the dermal papilla is not essential for the maintenance of the follicle itself since that part of the follicle remaining after the removal of the root end persists even if a dermal papilla is not regenerated and there is no fibre produced.

**SUMMARY**

1. A histological study has been made of the follicular changes which occur in vibrissa follicles both after the removal of the dermal papilla alone and the removal of various lengths of follicle root ('root ends').

2. The dermal papilla of the vibrissa follicle is not always a discrete and permanent entity, as it has been suggested to be in the feather follicle, since it can be regenerated.

3. No whisker is produced from a follicle or follicle remnant unless a dermal papilla is first regenerated.

4. Dermal papillae regenerate by tissue reorganization at, or just above, the puncture in the base of, or the cut across, the capsule. After removal of the dermal papilla alone, a new papilla of apparently normal size is regenerated, but dermal papillae which regenerate after removal of root ends are smaller than normal.

5. Examination of follicles after the removal of root ends demonstrates that the regeneration of dermal papillae and then whiskers occurs only within the lower third of the vibrissa follicle; there is little or no permanent lengthening, or shortening, of the follicle remnant—whether whiskers are regenerated or not. However, lengths of follicle remaining after removing root ends from within the upper two-thirds of the follicle persist—even though dermal papillae do not regenerate and no fibre production occurs.

6. The histological evidence strongly suggests that cells from the mesenchymal layer contribute to and possibly become the new dermal papilla. After removal of the dermal papilla or root end the outer root sheath cells coalesce to form a column or rod. Basophilia arises within the proximal end of this rod, over which the mesenchymal cells aggregate. These cells form the dermal papilla, first as a small indentation which then increases in size whilst acquiring a strongly basophilic ectodermal matrix.

**RÉSUMÉ**

*Etude histologique de la régénération de la moustache chez le rat (Hooded)*

1. L'auteur a fait une étude histologique des modifications qui surviennent dans les follicules des vibrisse après élimination de la papille dermique seule ou de diverses longueurs de la racine folliculaire (terminaisons radiculaires).

2. La papille dermique du follicule de la vibrisse peut se régénérer; elle n'est
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donc pas toujours une entité discrète et permanente comme on l'a suggéré à propos du follicule de la plume.

3. Aucun poil ne se forme à partir d'un follicule ou d'un reste folliculaire si la papille dermique n'a pas préalablement régénéré.

4. La papille dermique se régénère par réorganisation tissulaire au niveau de, ou juste au dessus de la piqûre ou l'incision capsulaire. Après élémination de la papille dermique seule, une nouvelle papille de taille apparaînt normale est régénérée, mais les papilles régénérées après enlèvement des terminaisons radiculaires sont plus petites que normalement.

5. L'examen des follicules après enlèvement des terminaisons radiculaires montre que la régénération des papilles dermiques et, par la suite, des poils, se produit seulement dans le tiers inférieur du follicule vibrissaire. Il n'y a pas ou peu d'allongement ou de raccourcissement permanent du résidu folliculaire que le poil soit régénéré ou non. Cependant, il peut persister des segments de follicule après élémination des terminaisons radiculaires dans les deux tiers supérieurs du follicule, même si les papilles dermiques ne régénèrent pas et qu'aucune production fibrillaire n'a lieu.

6. Des arguments histologiques suggèrent que des cellules de la couche mésenchymateuse contribuent à la formation de la nouvelle papille dermique et, peut-être, la forment. Après enlèvement de la papille dermique ou de la terminaison radiculaire, les cellules de la couche externe s'agglomerèrent pour former une colonne dans la partie proximale de laquelle apparait une basophilie tandis que les cellules mésenchymateuses s'y aggrègent. Ces cellules forment la papille dermique qui se présente d'abord comme une petite intumescence, laquelle s'accroit en acquérant une matrice fortement basophile.

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(Manuscript received 22 February 1966)