Equine vet. Educ. (2004) **16** (4) 201-206

Special Article

Skin of the neck, mane and tail of the curly horse

D. W. SCOTT

Departments of Clinical Sciences and Biomedical Sciences, College of Veterinary Medicine, Cornell University, Ithaca, New York 14853-6401, USA.

Keywords: horse; curly horse; skin; histoanatomy; follicular dysplasia

Introduction

The curly horse is becoming increasingly popular. Three registries currently represent the curly horse; the American Bashkir Curly Registry, the American Curly Horse Association and the International Curly Horse Organization. The International Curly Horse Organization (ICHO) was created to develop breeds of North American curly horses that will be officially recognised by the scientific community, and to strive to continually increase the base of factual knowledge about curlies. The interested reader is encouraged to visit the various websites listed at the end of this article.

Curly horses in North America were known to Native Americans; the Crow and the Sioux both had curlies (Thomas 1989). Curly horses were sacred horses, called 'Buffalo Ponies', to Native Americans and were owned by chiefs and medicine men.

The curly coat phenotype in most North American curly horses is a dominant trait (Thomas 1989). Curly coat is occasionally seen as a recessive trait in Quarter Horses, Percherons, Arabians, Appaloosas, Missouri Fox Trotters, Tennessee Walking Horses, Paints, Morgans and Paso Finos.

Curly horses come in varying degrees of curliness. Typically, the winter coat has curls in the form of tight ringlets to a marcel type wave (**Figs 1** and **2**). In the spring, the curly coat typically sheds out to a smoother or slightly wavy summer coat. Some curlies can shed in the spring to the point of patchy alopecia (**Fig 3**), followed by spontaneous regrowth of the hair coat.

The mane and tail hairs are also curly, wavy or in dreadlocks. Some curly horses also shed mane and tail hairs in the summer to the point of hypotrichosis or alopecia, followed by spontaneous regrowth. Other curly horses have varying degrees of persistent tail hypotrichosis, referred to as 'string tail' (**Fig 3**) or 'scanty tail' (**Fig 4**). The same horses typically have hypotrichotic manes as well (**Fig 5**).

Although the histology of normal skin from noncurly horses has been reported (Smith 1888; Jenkinson 1965; Talukdar *et al.* 1970, 1972; Talukdar 1973; Scott and Miller 2003), this author could find no such reports concerning curly horses. **The major purposes of this article are to 1) report the histoanatomy of normal curly horse skin and 2) describe a presumably hereditary follicular dysplasia of the mane and tail in curlies with the 'string tail' and 'scanty tail' phenotypes.**

Fig 1: Horse with extreme curly coat.

Fig 2: Close-up of horse in Figure 1.

TABLE 1: Clinical information on 18 'normal' curly horses*

Case	Age (years)	Sex	Phenotype
1	6	M	Moderate curly; scanty tail
2	13	F	Moderate curly
3	21	M	Moderate curly
4	2	F	Extreme curly; string tail
5	7	F	Mild curly
6	1	F	Mild curly
7	17	F	Moderate curly
8	2	M	Extreme curly; string tail
9	4	M	Moderate curly; scanty tail
10	12	F	Moderate curly
11	7	M	Moderate curly; scanty tail
12	1	F	Extreme curly; scanty tail
13	1	F	Mild curly
14	4	F	Extreme curly
15	8	F	Extreme curly; string tail
16	2	F	Moderate curly; scanty tail
17	10	M	Extreme curly
18	9	F	Moderate curly

*All curly horses with scanty tail or string tail also had hypotrichotic manes. M = male; F = female.

Materials and methods

The ICHO identified 18 curly horses in the USA and Canada for this study. All horses were believed to be free of skin disease, and were of various hair coat phenotypes (**Table 1**). The horses included 11 females and 7 intact males, and ranged from 1–21 years of age. Nine horses (*Cases 1–9*) were biopsied twice, in the autumn and again the following spring.

Local veterinarians were asked to take skin samples from the dorsolateral mane, lateral neck and dorsal tail base with a 6 mm biopsy punch instrument. Because veterinarians found tail-base biopsies very difficult to perform, only 4 autumn specimens (*Cases 1*, *4*, *8* and *9*) were received. In all, 58 skin biopsy specimens were examined. Skin biopsy specimens were placed in 10% neutral-buffered formalin and mailed to the author. Received specimens were processed routinely and stained with hematoxylin and eosin and acid orcein Giemsa.

In addition to routine histological examination, the following features were specifically examined (all measurements were made with a micrometer):

1. Skin thickness (subcutis not included)
2. Epidermal thickness
3. *Stratum corneum* thickness
4. Number of cell layers in the *stratum granulosum*
5. Ratio of melanocytes to keratinocytes in the *stratum basale*
6. Number of cell layers in the nucleated epidermis (*stratum granulosum*, *stratum spinosum*, *stratum basale*)
7. Number of mitotic keratinocytes per 6 mm specimen
8. Number of apoptotic keratinocytes per 6 mm specimen
9. Basement membrane zone thickness
10. Number of pilosebaceous units per 6 mm specimen
11. Number of anagen hair follicles per 6 mm specimen
12. Number of hair shafts per 6 mm specimen

Results

The histological appearance of curly horse skin was typical of that of mammalian skin in general and equine skin in specific (**Fig 6**) (Smith 1888; Jenkinson 1965; Talukdar *et al.* 1970, 1972; Talukdar 1973; Scott and Miller 2003). The surface was either smooth, gently undulating, or composed of ridges and grooves. Hair follicles opened into the grooves. Average skin thickness (subcutis not included) was 6.6, 3.8 and 5.3 mm, respectively, for the mane, lateral neck and tail base (**Table 2**). The subcutis was present in only 6 of 58 skin biopsy specimens.

The epidermis at all 3 sites was composed of a *stratum basale*, *stratum spinosum*, *stratum granulosum* and *stratum corneum*. In the mane and tail base, the *stratum granulosum* contained 2 cell layers and the *stratum spinosum* 4 or 5 cell layers. In the lateral neck, the *stratum granulosum* contained one cell layer and the *stratum spinosum* 3 or 4 cell layers. Rete ridges were present in the mane and tail base. Epidermal thickness averaged 105, 58.9 and 78.0 µm, respectively, in the mane, lateral neck and tail base (**Table 2**). The length of rete ridges in the mane and tail base averaged 181.6 µm (range 136–275 µm) and 114 µm (range 72.5–165 µm), respectively. The *stratum corneum* of the mane, lateral neck and tail base averaged 61.2, 39.8 and 26.9 µm, respectively, in thickness (**Table 2**).

Melanin granules were present in all layers of the epidermis, decreasing in quantity from the *stratum basale* to the *stratum corneum*. Melanin was also present in the *stratum basale* of the hair follicle outer root sheath as well as some sebaceous and epitrichial sweat gland ducts. Melanocytes, recognised as clear cells or melanised dendritic cells, were present in the *stratum basale* of the epidermis and the hair follicle outer root sheath. The melanocyte:basal keratinocyte ratio varied from 1:2–1:20. Dendritic melanocytes were occasionally seen subepidermally or near superficial dermal blood vessels. Langerhans' cells and Merkel's cells were not seen. A single mitotic figure in the *stratum basale* was seen in 1 mane and 2 neck specimens. A single apoptotic basal keratinocyte was seen in 1 mane and 1 neck specimen.

The basement membrane zone was easily recognised as a homogeneous, lightly eosinophilic structure. It averaged 5 µm (range 5 µm), 1.94 µm (range 1.5–3 µm) and 4 µm (range 3.5–5 µm), respectively, in the mane, lateral neck and tail base.

The dermis averaged 6.5, 3.7 and 5.2 mm in thickness in the mane, lateral neck and tail base, respectively. The arrangement of collagen fibres, elastin fibres (in acid orcein Giemsa-stained sections) and blood vessels was as previously described (Jenkinson 1965; Talukdar *et al.* 1970; Scott and Miller 2003). Dermal papillae were present in the mane and tail base. Lymphatic vessels were not seen above the middle dermis. Mast cells (in acid orcein Giemsa-stained sections) were present around superficial dermal blood vessels at an average of 3 (range 1–8) per high power field (HPF, x400 magnification) in all 3 cutaneous sites. Mast cells were not found in epidermis or hair follicle epithelium.

The microanatomy of hair follicles, sebaceous glands, epitrichial sweat glands and *arrector pili* muscles was as previously described (Jenkinson 1965; Talukdar *et al.* 1970,

TABLE 2: Histological measurements in skin biopsy specimens taken in the spring from 18 'normal' curly horses

Measurement	Mane		Lateral neck		Base of tail*	
	Mean	Range	Mean	Range	Mean	Range
Skin thickness (mm)†	6.6	3.5–10	3.8	2.5–7.7	5.3	2.5–6.4
Epidermal thickness (µm)	105	90–145	58.9	40–100	78.0	50–110
Stratum corneum thickness (µm)	61.2	50–75	39.8	25–50	26.9	15–60

*Only 4 horses sampled. †Subcutis not included.

1972; Scott and Miller 2003). No curly hair follicles or curly hairs were seen.

The average number of pilosebaceous units per 6 mm biopsy specimen was 9.1 (range 6–15), 10.6 (range 6–15) and 9 (range 8–11) for the mane, lateral neck and tail base, respectively. The average number of anagen hair follicles per 6 mm biopsy specimen was 5.2 (range 2–9), 5.1 (range 2–9) and 4.2 (range 2–7) for the mane, lateral neck and tail base, respectively. The percentage of hair follicles in anagen ranged from 30–75, 25–70 and 25–63.6% in specimens from the mane, lateral neck and tail base, respectively. The average number of hair shafts per 6 mm biopsy specimen was 5.2 (range 2–9), 5.4 (range 3–9), and 5.5 (range 4–7) in the mane, lateral neck and tail base, respectively.

Histological appearance and specific measurements of the skin biopsy specimens repeated in the autumn in *Cases 1–9* were not different from those reported above for the spring specimens. Neither were there differences between horses with different degrees of coat curliness. Single mitotic figures were seen in the *stratum basale* of 3 lateral neck and 2 mane specimens. Single apoptotic basal keratinocytes were seen in 3 mane and lateral neck specimens.

Unexpected histological findings were encountered in some of the horses (**Table 3**). Hyperkeratotic (orthokeratotic) hair follicles (**Fig 7**) were seen in 3/18 spring manes, 4/9 autumn manes and 1/4 autumn tail bases. Four of the 8 abnormal samples came from horses with hypotrichotic manes and tails. Dysplastic hair shafts (**Figs 8** and **9**) were found in 5/18 spring manes, 2/9 autumn manes and 4/4 autumn tail bases. Eight of the 11 abnormal samples came from horses with hypotrichotic manes and tails. Sebaceous gland melanosis (**Fig 10**) was observed in 1/18 spring manes, 1/9 autumn manes and 1/4 autumn tail bases. Two of the 3 abnormal samples came from horses with hypotrichotic manes and tails. None of these unexpected histological findings were present in samples from the lateral neck.

Discussion

One of the potential sources of error in this study is that different veterinarians in different parts of North America performed the biopsies. All participating veterinarians were given instructions on how the sites were to be selected and how the biopsies were to be performed. However, variations between veterinarians could partially explain why skin thickness values varied and why only 10.4% of the specimens contained subcutis. Having acknowledged that, the values reported here for skin thickness (subcutis not included), epidermal thickness and dermal thickness are remarkably similar to those reported by Talukdar *et al.* (1972) in their study of necropsy specimens.

The histoanatomy of normal curly horse skin is comparable to that of general equine skin in previous reports (Smith 1888; Jenkinson 1965; Talukdar *et al.* 1970, 1972; Talukdar 1973; Scott and Miller 2003). There are, however, some notable differences. Rete ridges and dermal papillae are reported not to occur in haired skin (Scott and Miller 2003), or to occur only in the tail base skin from noncurly horses (Talukdar *et al.* 1972). Rete ridges were present in both mane and tail base skin in curly horses, irrespective of hair coat phenotype. Melanocytes are reported to occur in the *stratum basale* of noncurly horses at a melanocyte:keratinocyte ratio of about 1:10–1:20 (Scott and Miller 2003). This ratio varied from 1:2–1:20 in curly horses.

Specific information on the frequency of finding mitotic figures or apoptotic keratinocytes in normal equine epidermis has not, to this author's knowledge, been reported previously. Single mitotic figures and apoptotic basal keratinocytes were found in only 13.8 and 12.1%, respectively, of the curly horse specimens examined.

Mast cells are difficult or impossible to identify in hematoxylin and eosin-stained equine skin specimens (Talukdar *et al.* 1972; Scott and Miller 2003). In one study of 10 normal horses (Shearer *et al.* 1995), there were significantly fewer mast cells identified by toluidine blue stain in formalin-fixed specimens as compared with Carnoy's-fixed specimens. In Carnoy's-fixed specimens stained with toluidine blue, the mean number of mast cells per HPF in the superficial dermis was 2.7. There was no variation between specimens procured from 10 different cutaneous sites. These observations agree with the findings in curly horses, wherein an average of 3 mast cells per HPF was found in formalin-fixed specimens stained with acid orcein Giemsa.

It has been suggested that the hair follicles of animals with curly hair are similarly curved or spiral shaped (Scott and Miller 2003). However, all hair follicles and hair shafts examined in curly horses were straight. It would appear that curling of the hair in curly horses develops after the hair shaft exits the hair follicle.

Many of the observations made in this study of curly horse skin have not previously been reported for equine skin. Therefore, comparisons cannot be made for the number of pilosebaceous units, anagen hair follicles and hair shafts present in 6 mm biopsy specimens; and the percentage of hair follicles that are in anagen.

Fig 3: Patchy alopecia as a result of spring shedding in a horse with an extreme curly coat. The horse also has a 'string tail'.

Fig 4: 'Scanty tail' in a curly coat horse during spring shedding.

Fig 5: Hypotrichotic mane in a horse with an extreme curly coat (same horse as in Figure 3). The horse also has a large area of alopecia over the neck as a result of spring shedding.

TABLE 3: Unexpected histological findings in skin biopsy specimens from 7 'normal' curly horses

	Follicular keratosis*	Dysplastic hair shafts†	Sebaceous gland melanosis
Spring specimens‡			
Case 3	1 of 8	1 of 4	
Case 4	2 of 7	2 of 4	
Case 5	-	1 of 4	
Case 6	-	1 of 7	+
Case 9	1 of 9	1 of 3	
Autumn specimens			
Mane			
Case 1	-	1 of 3	+
Case 3	2 of 10	-	
Case 4	2 of 7	-	
Case 5	6 of 8	-	
Case 6	4 of 8	-	
Case 9	-	4 of 5	
Tail			
Case 1	-	2 of 7	
Case 4	-	1 of 5	
Case 8	-	2 of 4	+
Case 9	3 of 8	1 of 6	

*No. hyperkeratotic hair follicles out of total number present; †No. dysplastic hair shafts out of total number present; ‡All specimens from the mane.

Although the density and quality of curly horse hair coat can be dramatically different in the spring and autumn, seasonal differences were not found in any histological parameter. Neither were differences found between horses with different hair coat phenotypes.

Follicular hyperkeratosis (orthokeratotic), dysplastic hair shafts and sebaceous gland melanosis were occasional findings in curly horse skin. Follicular keratosis was observed in from 1/9 to 6/8 hair follicles in 5/18 (27.8%) horses, predominantly in the mane. Follicular keratosis is a common histopathological finding in numerous dermatoses (Scott and Miller 2003). However, these curly horses were not known to have any skin disease.

Dysplastic hair shafts accounted for 1/7 to 4/5 hairs present in 6/18 (33.3%) horses, exclusively on the mane and tail base. Dysplastic hair follicles and hair shafts have been described in dogs with various clinical follicular dysplasia syndromes (Rothstein *et al.* 1998; Scott *et al.* 2001a) and *alopecia areata* (Scott *et al.* 2001b). Comparable follicular dysplasia syndromes do not occur in man. Dysplastic hair shafts have also been reported to occur in *alopecia areata* (von Tscharner *et al.* 2000; Scott and Miller 2003) and poorly documented clinical follicular dysplasia syndromes in horses (Scott 1999; Scott and Miller 2003). Again, the curly horses reported herein were not known to have any skin disease.

Sebaceous gland melanosis was observed in 3/18 (16.7%) curly horses, exclusively from the mane and tail base. Sebaceous gland melanosis is typically associated with endocrinopathies and clinical follicular dysplasia syndromes in dogs (Bagladi *et al.* 1996). Sebaceous gland melanosis was found in only 1.9% of 323 horses with various dermatoses, and none of 6 normal horses (Scott 1999). None of the curly horses reported herein were known to have skin disease.

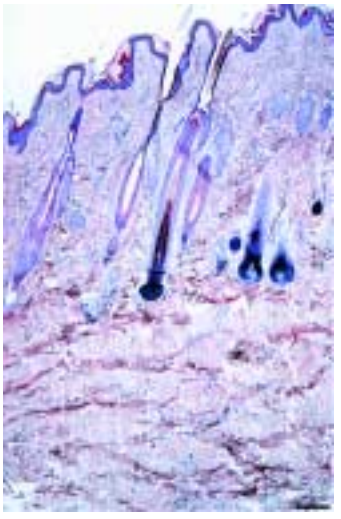

Fig 6: Photomicrograph of skin from lateral neck. Note simple hair follicle anatomy and straight hair shafts (H&E). *Scale bar 240 µm.*

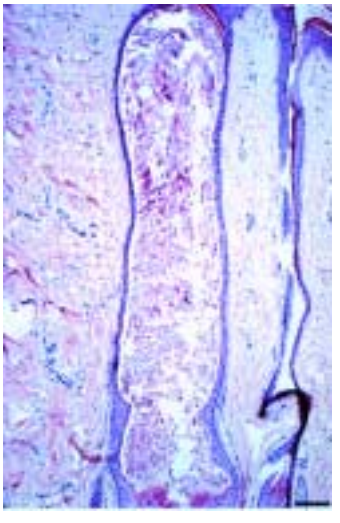

Fig 7: Photomicrograph of skin from mane. Note prominent orthokeratotic follicular hyperkeratosis (H&E). *Scale bar 95 µm.*

Taken together, the histopathological findings of dysplastic hair shafts, sebaceous gland melanosis and follicular keratosis are compatible with a pathological diagnosis of follicular dysplasia (Rothstein *et al.* 1998; Scott *et al.* 2001b). Mane and/or tail dysplasias (dystrophies) are reported to occur in a number of equine breeds, particularly in Appaloosas (Moriello *et al.* 1998; Pascoe and Knottenbelt 1999; Scott 1999; Scott and Miller 2003). Although the curly horses studied herein had no skin diseases, 8 of the 18 horses did have an accepted 'normal' trait; hypotrichotic manes and tails. It is interesting to note that 8 of the 11 skin specimens wherein dysplastic hair shafts were found came from hypotrichotic manes or tails. It is likely that the unusual manes and tails in these curly horses are not normal, but represent a trait-related follicular dysplasia. It is also likely that the follicular dysplasia is genetically determined, as it is presumed to be in many dog breeds (Scott *et al.* 2001b).

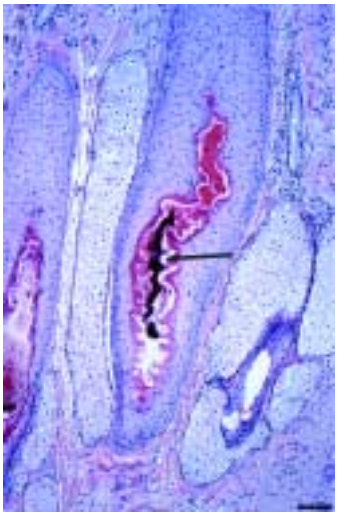

Fig 8: Photomicrograph of skin from mane. Note heavily melanised dysplastic hair shaft (arrow) (H&E). *Scale bar 95 µm.*

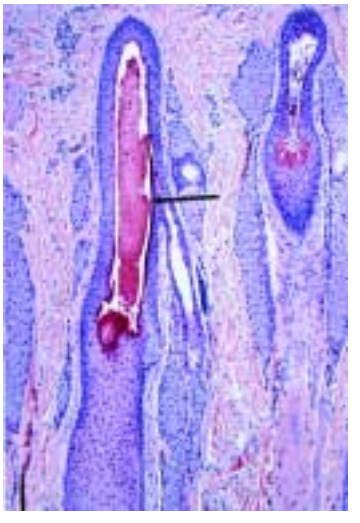

Fig 9: Photomicrograph of skin from mane. Note eosinophilic dysplastic hair shaft (arrow) (H&E). *Scale bar 95 µm.*

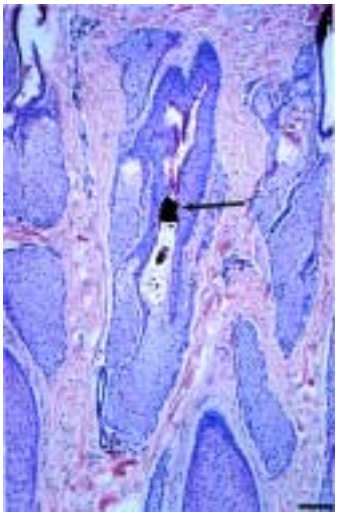

Fig 10: Photomicrograph of skin from mane. Note clumps of melanin within sebaceous duct (arrow) (H&E). *Scale bar 95 µm.*

Another possible cause of the hypotrichotic manes and tails in these curly horses is the autoimmune disorder *alopecia areata* (von Tscharner *et al.* 2000; Scott *et al.* 2001a; Scott and Miller 2003). In some cases of this disease, serial sections of multiple biopsies are required in order to demonstrate the characteristic lymphocytic bulbitis. However, it is highly unlikely that a seemingly rare condition such as *alopecia areata* could be present so commonly as a heritable trait in curly horses.

In conclusion, the histoanatomy of normal skin from curly horses is similar to that from noncurly horses. However, the various forms of mane and tail hypotrichosis in curly horses, presently accepted as 'normal' phenotypic variations, appear to be forms of follicular dysplasia. Further clinical, histopathological and genetic studies should be performed in order to confirm and clarify these findings.

Acknowledgements

The author thanks the International Curly Horse Organization for their enthusiastic and invaluable support. In addition, thanks are given to all the curly horse owners and veterinarians without whom this study would not have been possible.

Curly horse websites

American Curly Horse, http://www.angelfire.com/bc/amcurly/breed2.html
ICHO Photo Pages, http://members.aol.com/CurlyHorse/pics.html
International Curly Horse Organization, http://www.curlyhorses.org
International Curly Horse Organization Frequently Asked Questions, http://members.aol.com/CurlyHorses/FAQ.html
International Curly Horse Organization Glossary of Terms, http://members.aol.com/curlyhorses/glossary.html

References

Bagladi, M.S., Scott, D.W. and Miller, W.H. (1996) Sebaceous gland melanosis in dogs with endocrine skin disease or follicular dysplasia: a retrospective study. *Vet. Dermatol.* **7**, 85-90.

Jenkinson, D.M. (1965) The skin of domestic animals. In: *Comparative Physiology and Pathology of the Skin*, Eds: A.J. Rook and G.S. Walton, Blackwell Scientific Publications, Oxford. pp 591-608.

Moriello, K.A., DeBoer, D.J. and Semrad, S.D. (1998) Diseases of the skin. In: *Equine Internal Medicine*, Eds: S.M. Reed and W.M. Bayly, W.B. Saunders Co., Philadelphia. pp 513-557.

Pascoe, R.R. and Knottenbelt, D.C. (1999) Congenital/developmental disorders. In: *Manual of Equine Dermatology*, W.B. Saunders Co., Philadelphia. p 147.

Rothstein, E., Scott, D.W., Miller, W.H. and Bagladi, M.S. (1998) A retrospective study of dysplastic hair follicles and abnormal melanization in dogs with follicular dysplasia syndromes or endocrine skin disease. *Vet. Dermatol.* **9**, 235-241.

Scott, D.W. (1999) Sebaceous gland melanosis in the horse. *Vet. Dermatol.* **10**, 157.

Scott, D.W. and Miller, W.H. (2003) Structure and function, immune-mediated disorders, congenital and hereditary skin diseases. In: *Equine Dermatology*, W.B. Saunders Co., Philadelphia. pp 1-646.

Scott, D.W., Miller, W.H. and Griffin, C.E. (2001a) Immune-mediated disorders. In: *Muller & Kirk's Small Animal Dermatology VI*, W.B. Saunders Co., Philadelphia. pp 761-764.

Scott, D.W., Miller, W.H. and Griffin, C.E. (2001b) Congenital and hereditary defects. In: *Muller & Kirk's Small Animal Dermatology VI*, W.B. Saunders Co., Philadelphia. pp 959-973.

Shearer, D.H., Green, F.K. and Lee, A.L. (1995) A study of the number and distribution of cutaneous mast cells in the horse. *Proc. Eur. Soc. Vet. Dermatol.* **12**, 250.

Smith, F. (1888) The histology of the skin of the horse. *Vet. J.* **26**, 333-340.

Talukdar, A.H. (1973) A histological study of the dermo-epidermal junction in the skin of the horse. *Res. vet. Sci.* **15**, 328-332.

Talukdar, A.H., Calhoun, M.L. and Stinson, A.W. (1970) Sweat glands of the horse: a histologic study. *Am. J. vet. Res.* **31**, 2179-2190.

Talukdar, A.H., Calhoun, M.L. and Stinson, A.W. (1972) Microscopic anatomy of the skin of the horse. *Am. J. vet. Res.* **33**, 2365-2390.

Thomas, S. (1989) *Myth and Mystery: The Curly Horse in America,* C.S. Fund, Inc., Freestone.

von Tscharner, C., Kunkle, G. and Yager J. (2000) Stannard's illustrated equine dermatology notes. *Vet. Dermatol.* **11**, 195-198.