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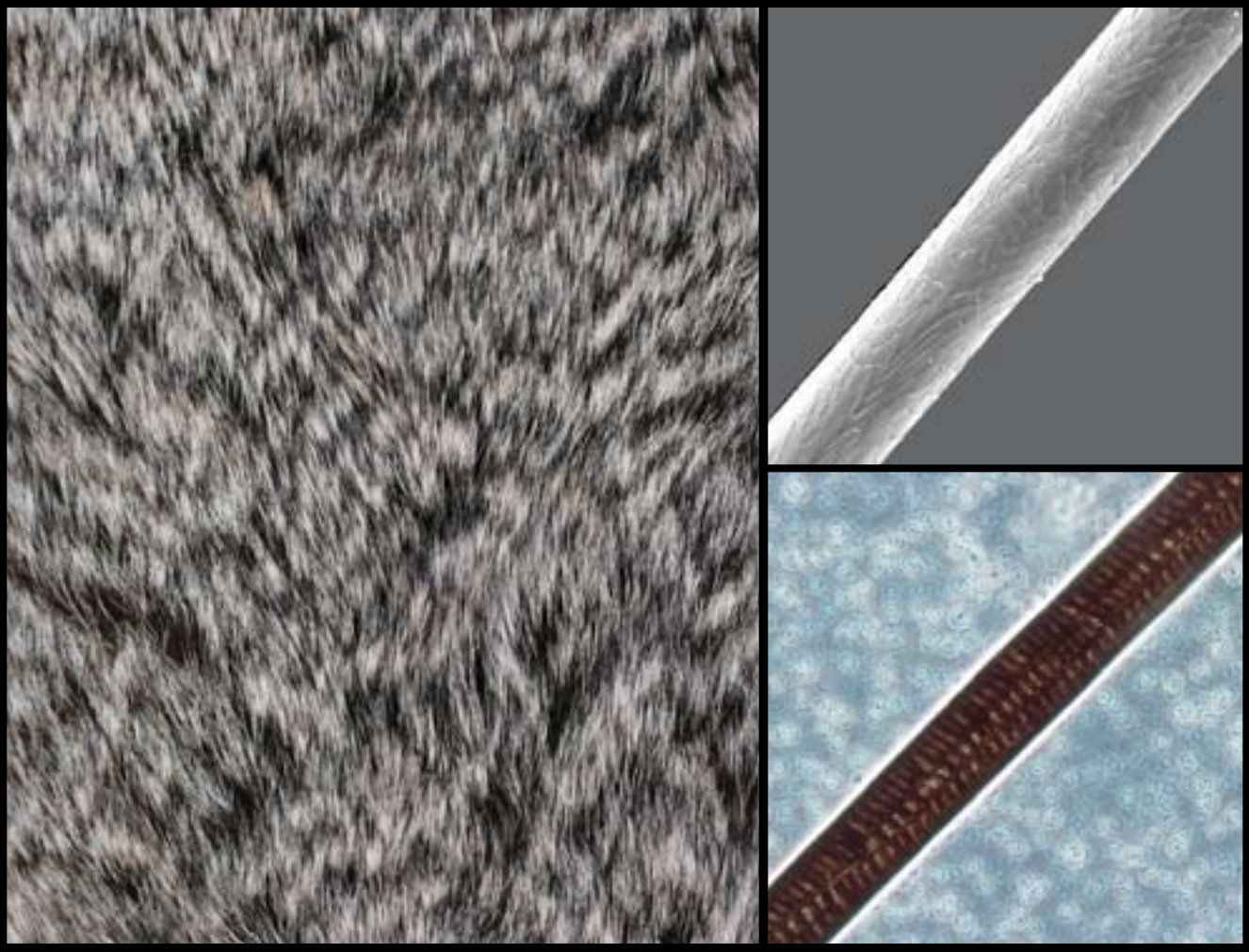
Atlas and Key to the Hair of Terrestrial Texas Mammals



Anica Debelica and Monte L. Thies

Front cover: Pelage, SEM image, and photomicrograph of black-tailed jackrabbit, *Lepus californicus* (pelage of SHM 510; SEM and micrograph of SHM 38). Cover design by M. L. Thies.

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Atlas and Key to the Hair of Terrestrial Texas Mammals

Anica Debelica and Monte L. Thies

Abstract

Even though some hairlike structures may be found on organisms such as birds, insects, and plants, true epidermal hair is a unique characteristic of mammals. Samples of guard hairs from over 150 mammalian species found in Texas were collected from specimens housed in natural history collections or, as in the case for domestic farm animals, were obtained from living animals. An atlas and key were developed after examining several characters of hair samples, including average diameter of the hairs, structure of the medulla, and arrangement of cuticular scales. Digital photographs of the medulla and SEM images of the hair's surface accompany the key and should provide a helpful tool for hair identification.

Key words: atlas, dorsal guard hair, hair identification, key, terrestrial mammals, Texas

Introduction

Even though hairlike structures may be found on organisms such as birds, insects, and plants, true epidermal hair is a unique characteristic of mammals. In most mammals, hair is conspicuous, but in some, such as some whales, hair is represented by only a few bristles on the embryo (DeBlase et al. 2001).

Most hair identification in the past has been done by specialists who learned their craft by comparing unknown with known samples. This process necessitated patience, years of practice, and an extensive reference collection of hairs (Williams 1938). Williams (1938) believed that "there is a real need for the definition and illustration of diagnostic characters of hairs and the preparation of keys that may be used successfully by others than specialists." Keys and atlases to mammalian hair of different regions of the world would be of great help in studies of food habits of predatory mammals and birds, such as mountain lions and owls, respectively, because in these studies scientists often examine hairs found in fecal samples in order to determine what those animals were eating. These keys could also facilitate identification of hair found at crime scenes or be useful in species identifications of material recovered in illegal trade of wildlife parts.

Despite the potential uses that keys to mammalian hairs may have, few fully developed keys and atlases have been published. Numerous scientists in the United States, such as Hausman (1920), Cole (1924), Mathiak (1938), Williams (1938), Brown (1942), Nason (1948), Mayer (1949, 1952), Benedict (1957), Stains (1958), Miles (1965), Short (1978), Moore et al. (1974), Gaisler and Barus (1978), Homan and Genoways (1978), Hess et al. (1985), Hickey and Fenton (1987), Stangl and Grimes (1987), van Staaden and Jones Jr. (1997), and Amman et al. (2002) have conducted descriptive and comparative studies of mammalian hairs. They have expanded our knowledge on structure and appearance of hair, as well as the taxonomic and phylogenetic value of hair. Unfortunately, most of these studies, with the exception of Mathiak (1938), Mayer (1952), Stains (1958), and Moore et al. (1974), focused on a limited number of taxa from specific families or genera instead of focusing on all of the mammals from a specific region. In addition, scientists conducting these studies argued about the usefulness of hair properties in resolving phylogenetic problems in groups such as New World bats. Cole (1924), Nason (1948), Benedict (1957), Miles (1965), and Short (1978) believed that hair is of very limited taxonomic value, whereas

Mathiak (1938), Williams (1938), and Brown (1952) believed the opposite. Amman et al. (2002) provided an analysis of hair structure in bats from Colorado, effectively demonstrating the utility of SEM in differentiation among a limited number of species from a limited geographic area.

In the last few decades, only a few scientists have provided complete regional keys to mammalian hairs such as "A key to the hairs of the mammals of Southern Michigan" (Mathiak 1938), "The hair of California mammals with keys to the dorsal guard hairs of California mammals" (Mayer 1952), "Field key to guard hair of Middle Western furbearers" (Stains 1958), and "Identification of the dorsal guard hairs of some mammals of Wyoming" (Moore et al. 1974). In Europe, Lochte (1938) published an atlas to hairs, Keller (1978; 1980; 1981a, b) published papers providing keys and valuable information concerning hair characters, and Teerink (1991) published an atlas and identification key to hair of Western European mammals.

Hair formation.—The primary development of hair begins as a localized proliferation of epidermal cells forming a dense aggregation of cells, which elongates downward into the dermis. The dermal cells, beneath this downward-elongated, flask-shaped depression of the epidermal cells, form a dense mass that ultimately forms the papilla of the hair. This flask-shaped depression becomes lined with cells of the epidermis becoming a follicle (Hausman 1920). The epithelial contents of the growing follicle elongate into an avial strand of fusiform, spindle cells, which undergoes keratinization and forms the hair shaft. The lower part of the shaft expands into a bulb that wraps the papilla while the shaft elongates upward and emerges through the epidermis and continues to grow. Growth is confined to the proximal portion of the shaft where matrix cells continuously convert into keratinized hair shaft cells (Hausman 1920).

Hair structure.—The hair shaft consists of four structural units, the *medulla*, *cortex*, *pigment granutes*, and *cuticle* (Hausman 1920, Fig.1). *Medulla*: built up from many shrunken and variously disposed cells or chambers, representing dried and cornified epithelial structures connected by a branching filamentous network, which sometimes completely fills the medullary column, but is interrupted in many cases. *Cortex*: shell surrounding the medulla that is composed of elongate, fusiform cells (hair spindles) coalesced together into a horny, almost homogenous, hyaline mass and forming, in many cases where the medulla is reduced, a larger proportion of the hair shaft. *Pigment granules*: structures primarily responsible for the color of the hair; in some mammals pigment is difuse instead of granular. Granules are scattered within or between the hair spindles, and in some hairs they are arranged in definite patterns. *Cuticle*: outermost integument of a hair shaft composed of thin, hyaline, colorless scales of varying forms and dimensions.

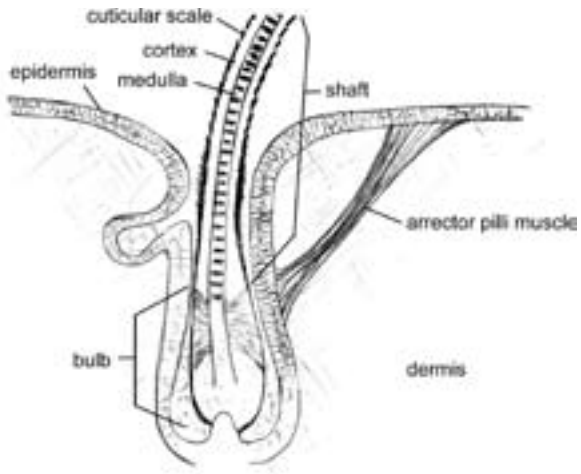

Figure 1. Sectional view of skin showing hair and various structures in dermis and epidermis (after Duperron 1997).

Classification and function of hair.—Hair can be divided into two major groups: (1) hairs with sensory function, and (2) all other or "normal" hair. "Normal" hair can be further divided into three subgroups: (a) heavy overhairs that are usually longer, straighter, and more robust throughout their length than the general coat in most mammals; (b) curly overhairs that are usually enlarged only in the distal third or half of their lengths, the basal portion being decidedly weaker and more flexible; and (c) furhairs that are uniformly weak and flexible except at the tip and base (Williams 1938). Both (a) and (b) are together known as guard hair.

The objective of this project was to provide a key and atlas to the hairs of Texas land mammals that would be relatively easy for anyone to use. Digital photographs of the medulla and SEM images of the surface (scales) of guard hairs accompany the key to provide aids in hair identification.

METHODS AND MATERIALS

Hair samples of over 150 species of land mammals found in Texas (following Schmidly 2004) were collected from specimens in the mammal holdings of the Sam Houston State Vertebrate Museum (SHM), Huntsville, Texas; the Angelo State Natural History Collection (ASNHC), San Angelo, Texas; the Texas Cooperative Wildlife Collection (TCWC) at Texas A&M University, College Station, Texas; the Oklahoma State University Collection of Vertebrates (OSUCOV), Stillwater, Oklahoma; and the Museum of Texas Tech University (TTU), Lubbock, Texas. In addition, samples were provided by the Houston Zoological Park, Houston, Texas; and R. Smith, Huntsville, Texas.

Although underhair had been used in previous studies (Hausman 1920, 1930; Cole 1924), this study focused on dorsal guard hair. This is the type of hair that scientists or law enforcement investigators would most likely encounter in their work. Guard hair is more robust and larger in length and diameter than underhair and is most likely to be detected in biological samples and at crime scenes. Nason (1948) pointed out that "hairs from the center of the mid-dorsal region would be typical for a species and be an adequate basis for comparing one with another." According to Teerink (1991), there are three types of guard hair: GH0, GH1, and GH2. GH0 hair is stiff, firm, and straight, but it seldom occurs within pelage. GH1 hair is usually stiff and firm, occurs very often within pelage, and its shield (hair's thickest part) is somewhat closer to the tip. In some mammals, it can be slightly wavy or bent. In GH2, the shield and shaft usually form an angle with each other. The shaft is usually straight, but it can also be wavy to different degrees. It also occurs often in pelage like GH1. Teerink (1991) suggested that GH1 and GH2 provide the most information that can be used to build a key, and that four features of GH1 and GH2 are important for identification: (1) the cuticula in shaft and proximal shield; (2) cross-section through the shield; (3) medulla in the thickest part of the shield; and (4) medullar margins in the thickest part of the shield. However, Benedict (1957), Gaisler and Barus (1978), Hickey and Fenton (1987), and van Staaden and Jones Jr. (1997) all agreed "that only the scales in the mid-region of a hair shaft are the mature and uniform types" (Benedict 1957). In this study, dorsal guard hairs were collected from the central mid-dorsal region of specimens and scales and medulla from the mid-region of the hair shaft were used.

Preparation of slides.—Hairs were cleaned and freed of grease (in tepid water with detergents) and stored in 70% ethanol. For medullar slides, hairs were immersed in paraffin oil before being mounted on slides and covered with a cover glass: the paraffin oil penetrates the medulla and enables visualization of the medulla structure (Teerink 1991). Slides were examined with Olympus BX41 and Olympus DP11 compound microscopes at 400X magnification.

The medulla was classified following Hausman (1920) as Discontinuous (Fig. 2 Simple, Fig. 3 Compound, Fig. 4 Fragmental) or Continuous (Fig. 5 Nodose, Fig. 6 Homogeneous).

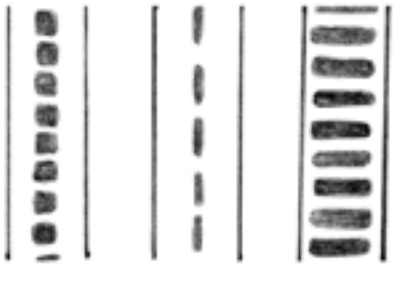

Figure 2. Simple medulla types: (a) Ovate, (b) Elongate, and (c) Flattened.

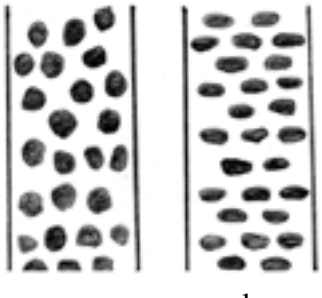

Figure 3. Compound medulla types: (a) Ovate and (b) Flattened.

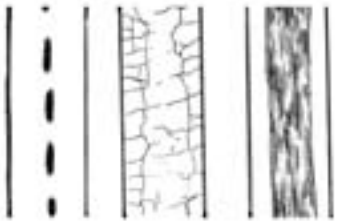

Figure 4. Fragmental medulla types (a), (b), and (c).

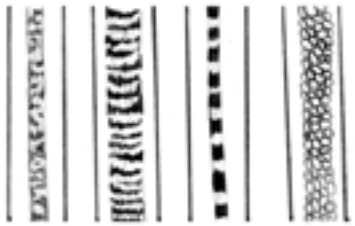

Figure 5. Nodose medulla types (a) and (b).

Figure 6. Homogeneous medulla types (a) and (b).

Hair profile slides were used for the measurements (length and diameter). Following Moore et al. (1974) hairs were examined for shape and shield location, color (bicolored or multicolored), and color band pattern (number and position of bands). However, of these characteristics, only diameter was included in the keys because length, coloration, banding pattern, and shield position are too variable and may be misleading due to the seasonal changes. Complete hairs are also often lacking in a sample.

Preparation of SEM material.—Scanning electron microscope (SEM) images of hair surfaces (scales) were taken following methods as described by Stangl and Grimes (1987). Entire hairs were mounted on specimen stubs using two-sided tape. Stubs were then sputter coated with gold and the coated specimens examined with a HiVac SEM "Vega TC."

Because bat hair lacks a medulla, has limited variation in scale types, and is generally difficult to distinguish, scale indexes (SI = maximum scale width/maximum scale length) and width index (WI = maximum/minimal scale width) were determined as an additional identification tool. All hairs were classified according to their scales type (Figs. 7-8) following Hausman (1920) and Nason (1948).

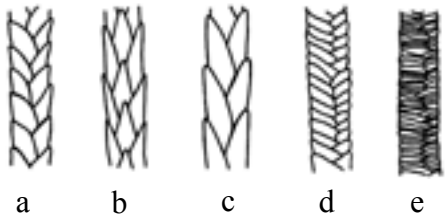

Figure 7. Imbricate cuticula types: (a) Ovate, (b) Acuminate, (c) Elongate, (d) Crenate, and (e) Flattened.

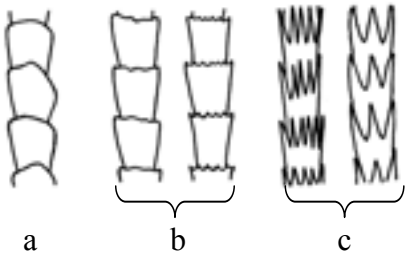

Figure 8. Coronal types of scales: (a) Simple, (b) Serrate, and (c) Dentate.

RESULTS

An ordinal key to the hair of terrestrial Texas mammals, as well as the species keys for each order, were constructed using three primary hair characteristics: medulla type, scale type, and shaft diameter. For Chiroptera (bats), medulla type was replaced by two characters – scale index (SI) and width index (WI). Each key to order is followed by an atlas of species occurring in Texas, a brief description of hair characteristics, a digital photograph of the medulla, and an SEM image of the cuticula (Figs. 9-159). Common domestic or non-native but free-ranging species such as house mice (*Mus musculus*), feral hogs (*Sus scrofa*), and nutria (*Myocastor coypus*) are indicated by an asterisk.

Glossary of Terms

"Cells" – The shape of medullar "cells" may be oval, rectangular, square, or flattened.

Columns/rows – The absence, presence, arrangements, and any disturbances of medullar cells within columns and/or rows.

Coronal cuticula (Fig. 8) – Only one scale in each row completely encircling the hair.

Discontinuous medulla (Figs. 2-4) and C*ontinuous medulla* (Figs. 5-6) – Type of arrangement of "cells" and chambers within medullar column.

Imbricate cuticula (Fig. 7) – There are at least two scales in a single row of the cuticula.

Medulla – Central hair portion built up from many shrunken and variously disposed cells or chambers.

Medulla occupies entire shaft – Medulla is spread throughout the entire shaft, from one side to the other.

Medulla occupies >1/2 of the shaft – Medulla is spread throughout the central part of the shaft; it occupies more than 1/2 of the shaft, but not the entire shaft.

Medulla occupies 1/2 of the shaft – Medulla is found only in central part of the shaft and covers overall 1/2 of it.

Medulla occupies 1/3 of the shaft – Medulla is found only in central part of the shaft and covers overall only 1/3 of it.

Penetrated/not penetrated – If medullar structure is visible, then medulla is penetrated by the light. If medullar structure cannot be seen and the entire shaft appears dark, then medulla is not penetrated by the light.

*Scale index (SI) – C*alculated by dividing maximum width of the scale by the length of the scale. Replaces type of medulla in the identification of bat hair.

Vacuolated – Presence or absence of vacuoles in medulla.

Width index (WI) – Calculated by dividing maximum width of the scale by the minimal width of the scale. Replaces type of medulla in the identification of bat hair.

ORDINAL KEY TO THE HAIR OF TERRESTRIAL TEXAS MAMMALS

1. Medulla absent.....Chiroptera
   Medulla present.....2

2. Medulla discontinuous.....3
   Medulla continuous.....14

3. Medulla simple (Fig. 2).....4
   Medulla other than simple.....7

4. Medulla type a (Fig. 2).....5
   Medulla type c (Fig. 2).....6

5. Medulla occupies 1/3 of shaft.....Soricomorpha
   Medulla occupies entire shaft.....Rodentia

6. Medulla visible in cuticular photographs.....Soricomorpha
   Medulla not visible.....Rodentia

7. Medulla compound (Fig. 3).....8
   Medulla fragmental (Fig. 4).....10

8. Medulla other than ovate.....Rodentia
   Medulla ovate (Fig. 3).....9

9. Medulla with flattened cuticula (Fig. 7e).....Carnivora
   Medulla with other than flattened cuticula (Fig. 7a-d).....Rodentia

10. Medulla type b or c (Fig. 4).....Rodentia
    Medulla type a (Fig. 4).....11

11. Medulla with flattened cuticula (Fig. 7e).....Perissodactyla
    Medulla with crenate cuticula (Fig. 7d).....12

12. Medulla with cortical intrusions.....Rodentia
    Medulla with no cortical intrusions.....13

13. Medulla extremely fragmented and present in small fragments, medulla occupies less than 1/3 of shaft.....Primates
Medulla present in large fragments, medulla occupies almost 1/2 of shaft.....Artiodactyla

14. Medulla homogeneous (Fig. 6).....15
Medulla nodose (Fig. 5).....17

15. Medulla occupies less than 1/3 of shaft.....Cingulata
Medulla occupies more than 1/3 of shaft.....16

16. Medulla not penetrated, scales flattened (Fig. 7e).....Artiodactyla
Medulla not penetrated, scales crenate (Fig. 7d).....Carnivora

17. Medulla nodose type a (Fig. 5a).....18
Medulla nodose type b (Fig. 5b).....20

18. Medulla vacuolated.....Carnivora
Medulla not vacuolated.....19

19. Shaft d>100µm.....Didelphimorphia
Shaft d< 100µm.....Rodentia

20. Medulla ordered into columns.....Lagomorpha
Medulla not ordered into columns.....21

21. Medulla disturbed.....22
Medulla undisturbed.....24

22. Cuticula flattened (Fig. 7e).....Artiodactyla
Cuticula crenate (Fig. 7d).....23

23. Medulla occupies 1/3 of shaft.....Artiodactyla
Medulla occupies more than 1/2 of shaft.....Rodentia

24. Medulla "cells" not flattened.....Artiodactyla
Medulla "cells" flattened.....25

25. Medulla vacuolated.....Carnivora
Medulla not vacuolated.....Rodentia

ORDER DIDELPHIMORPHIA - OPOSSUMS

Medulla continuous, nodose type a (Fig. 5a), non-vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, crenate (Fig. 7d), disturbed rows. Midshaft dia. 130µm.....*Didelphis virginiana* (Fig. 9)

Family Didelphidae

***Didelphis virginiana* - Virginia Opossum** (SHM 6)

Medulla continuous, nodose type a, occupies more than 1/2 of shaft. Cuticula imbricate, crenate, disturbed rows. Midshaft dia. 130µm.

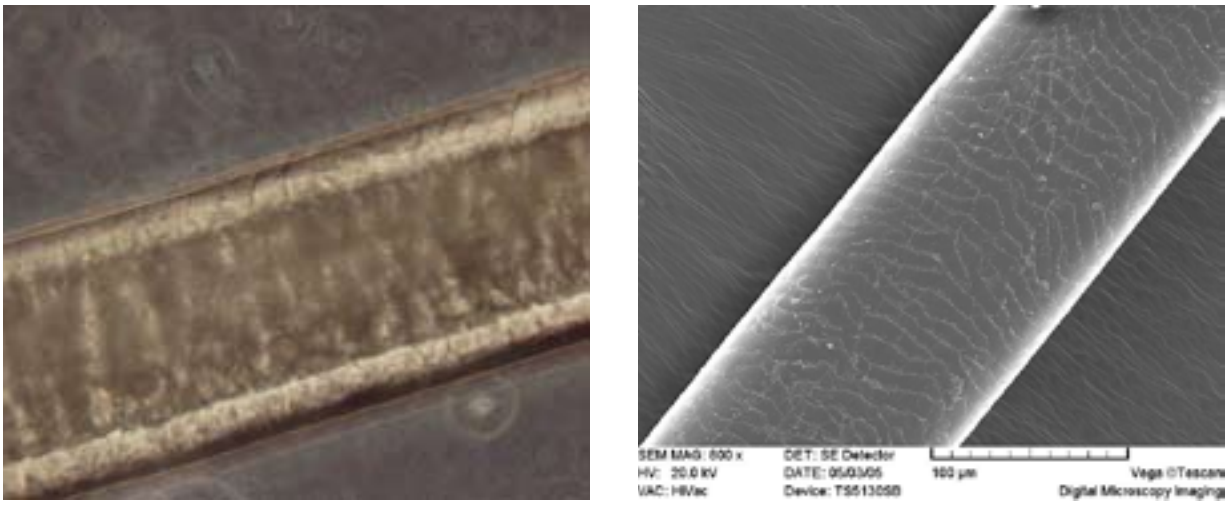

Figure 9. Medulla (left) and cuticula (right) of *Didelphis virginiana*.

ORDER CINGULATA - ARMADILLOS

Medulla continuous, homogeneous type a (Fig. 6a), occupies less than 1/3 of shaft. Cuticula imbricate, crenate (Fig. 7d), irregular scales with no apparent rows. Midshaft dia. 200µm.....*Dasypus novemcinctus* (Fig. 10)

Family Dasypodidae

***Dasypus novemcinctus* - Nine-banded Armadillo** (SHM 171)

Medulla continuous, homogeneous type a, occupies less than 1/3 of shaft. Cuticula imbricate, crenate, scales irregular with no apparent rows formed. Midshaft dia. 200µm.

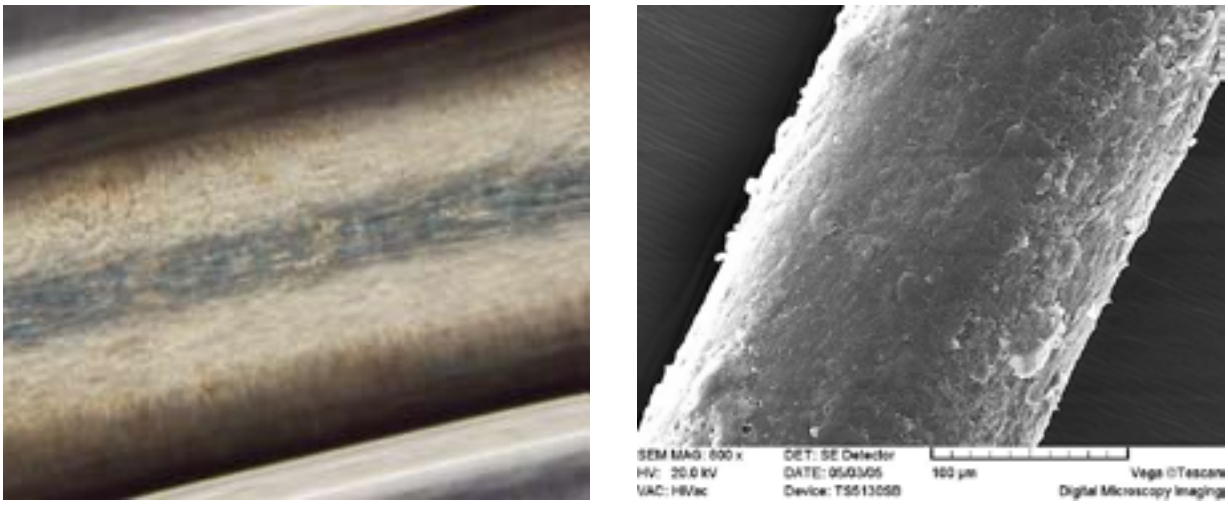

Figure 10. Medulla (left) and cuticula (right) of *Dasypus novemcinctus*.

ORDER SORICOMORPHA - SHREWS AND MOLES

All have discontinuous simple medulla (Fig. 2).

1. Medulla simple type a (Fig. 2a).....*Blarina carolinensis* (Fig. 11)
   Medulla simple type c (Fig. 2c).....2

2. Medulla "cells" flattened.....3
   Medulla "cells" not flattened.....4

3. Cuticula crenate (Fig. 7d).....*Blarina hylophaga* (Fig. 12)
   Cuticula elongate (Fig. 7c).....*Cryptotis parva* (Fig. 13)

4. Medulla "cells" rectangular.....*Notiosorex crawfordi* (Fig. 14)
   Medulla "cells" variably shaped.....*Scalopus aquaticus* (Fig. 15)

Family Soricidae - Shrews

***Blarina carolinensis* - Southern Short-tailed Shrew** (SHM 380)

Medulla discontinuous, simple type a, occupies 1/3 of shaft. Cuticula imbricate, crenate, medulla visible. Mid-shaft dia. 44µm.

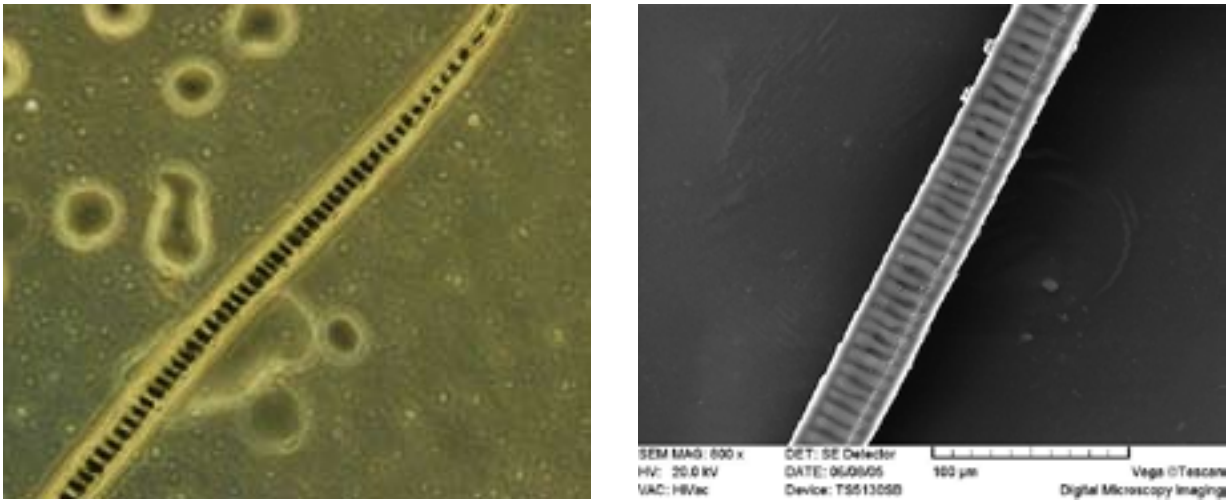

Figure 11. Medulla (left) and cuticula (right) of *Blarina carolinensis*.

***Blarina hylophaga* - Elliot's Short-tailed Shrew** (TTU 100794)

Medulla discontinuous, simple type c, very flattened "cells", occupies more than 1/2 of shaft. Cuticula imbricate, crenate, medulla visible in middle. Midshaft dia. 34µm.

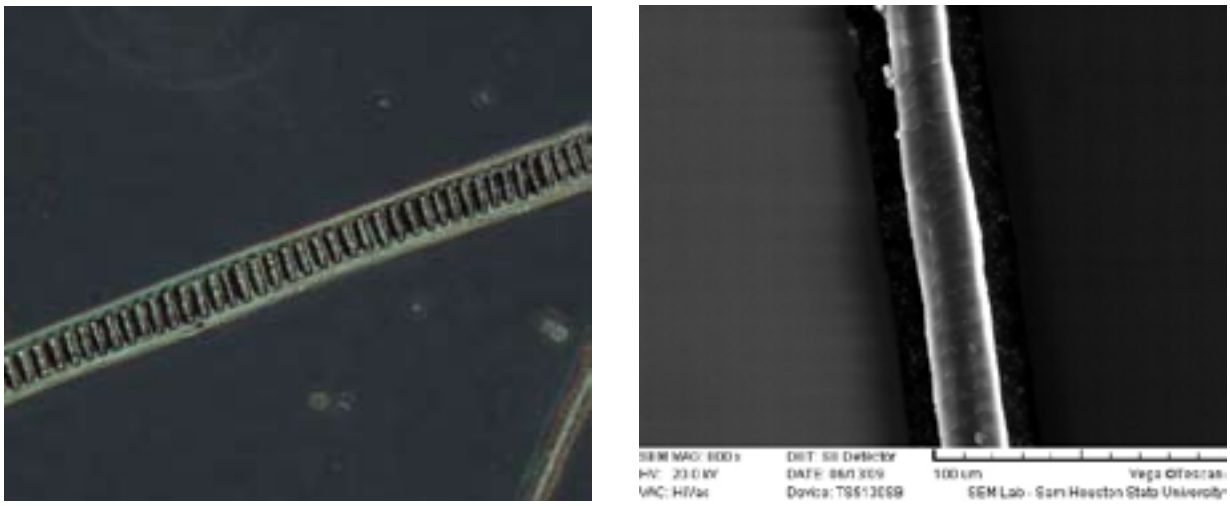

Figure 12. Medulla (left) and cuticula (right) of *Blarina hylophaga*.

***Cryptotis parva* - Least Shrew** (SHM 163)

Medulla discontinuous, simple type c, very flattened "cells", occupies more than 1/2 of shaft. Cuticula imbricate, elongate, medulla visible. Midshaft dia. 21µm.

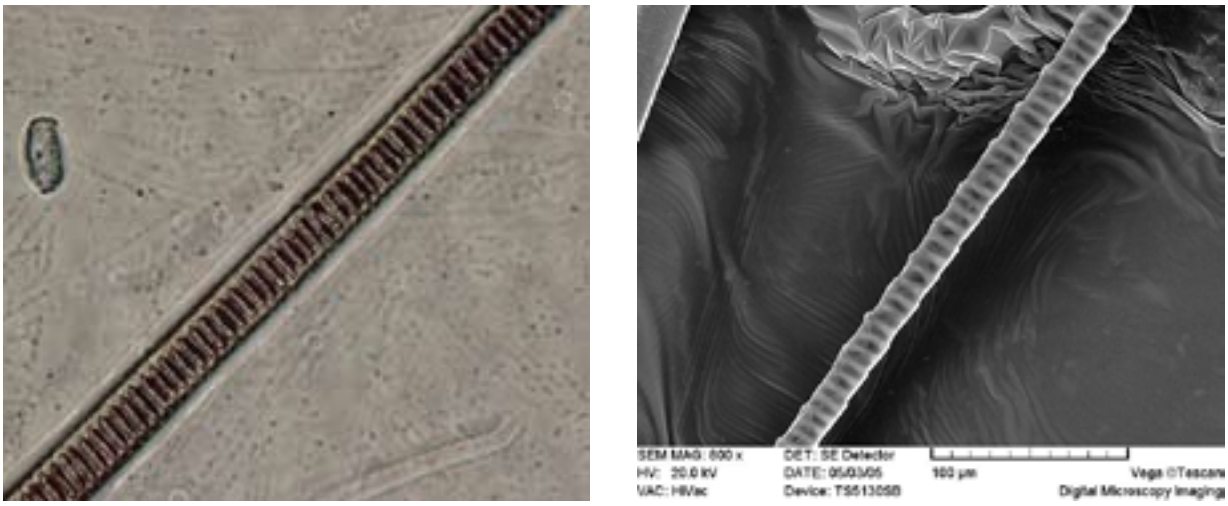

Figure 13. Medulla (left) and cuticula (right) of *Cryptotis parva*.

***Notiosorex crawfordi* - Desert Shrew** (SHM 37)

Medulla discontinuous, simple type c, rectangular "cells", occupies entire shaft. Cuticula imbricate, elongate, visible medulla. Midshaft dia. 23µm.

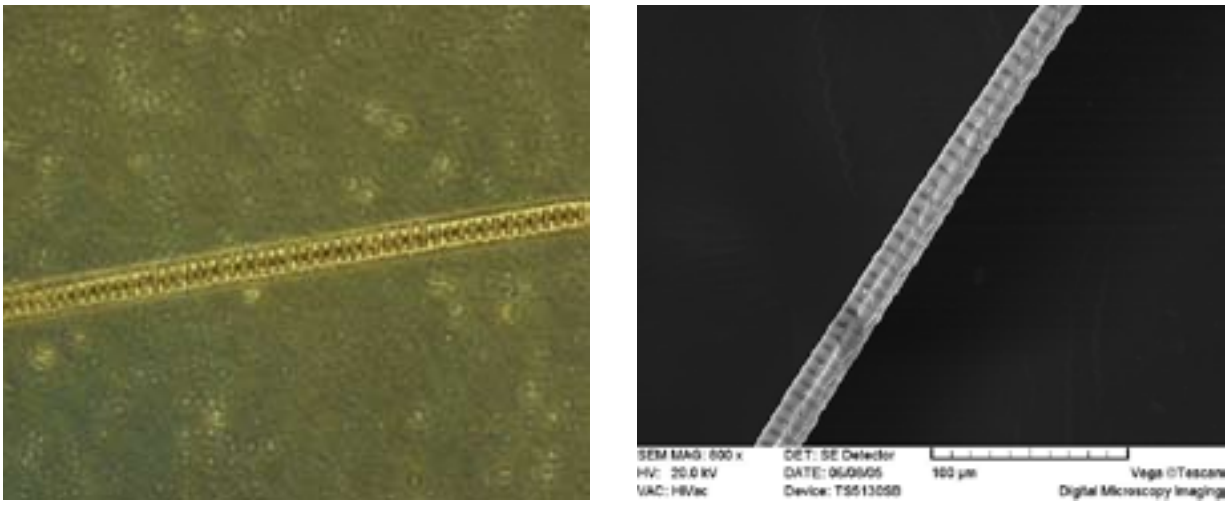

Figure 14. Medulla (left) and cuticula (right) of *Notiosorex crawfordi*.

Family Talpidae - Moles

***Scalopus aquaticus* - Eastern Mole** (SHM 198)

Medulla discontinuous, simple type c, mixed shapes of "cells" (elliptical, rectangular, and square), occupies entire shaft. Cuticula imbricate, elongate, visible medulla. Midshaft dia. 41µm.

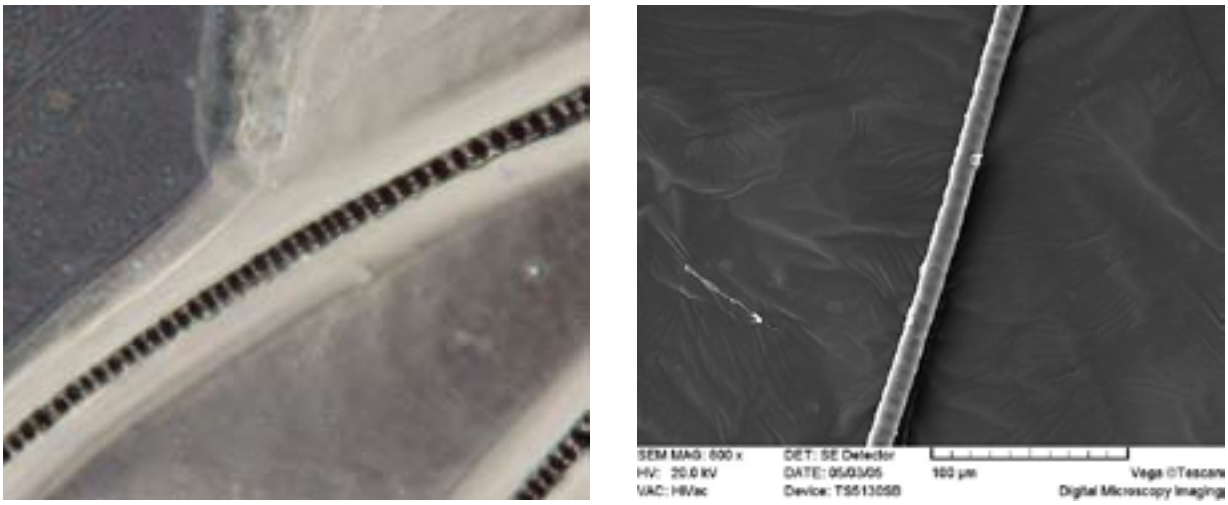

Figure 15. Medulla (left) and cuticula (right) of *Scalopus aquaticus*.

ORDER CHIROPTERA – BATS

All members of Chiroptera in Texas lack medulla and have coronal scales (Fig. 8). Scale index (SI) and width index (WI) are given for each species.

1. Cuticula dentate (Fig. 8c).....2
   Cuticula other than dentate.....5

2. Dentations very deep with one extremely deep.....*Tadarida brasiliensis* (Fig. 44)
   Dentations very small.....3

3. WI>2.....*Nyctinomops femorosaccus* (Fig. 45)
   WI<2.....4

4. WI<1.2.....*Eumops perotis* (Fig. 47)
   1.2<WI<2.....*Nyctinomops macrotis* (Fig. 46)

5. Cuticula serrate (Fig. 8b).....6
   Cuticula simple (Fig. 8a).....7

6. Scales relatively equal in size.....*Mormoops megalophylla* (Fig. 16)
   Each large scale followed by 2 small scales at each side.....*Leptonycteris nivalis* (Fig. 18)

7. SI<1.....8
   SI≥1.....26

8. WI≥2.....9
   WI<2.....11

9. Scale maximum d≥12µm.....*Corynorhinus rafinesquii* (Fig. 41)
   Scale maximum d<12µm.....10

10. Scale maximum d=10µm.....*Myotis californicus* (Fig. 21)
    Scale maximum d<10µm.....11

11. SI=0.4, WI≥2, scale maximum d=7µm.....*Myotis septentrionalis* (Fig. 23)
    SI=0.5, WI≥2, scale maximum d=7µm.....*Myotis volans* (Fig. 26)

12. WI=1.5 13
WI<1.5 17

13. SI=0.9 ..... *Myotis austroriparius* (Fig. 20)
SI<0.9 14

14. SI=0.7 15
SI<0.7 16

15. Scales funnel-shaped, uneven ..... *Lasiurus blossevillii* (Fig. 28)
Scales funnel-shaped, evenly shaped but unevenly arranged ..... *Myotis thysanodes* (Fig. 24)

16. SI=0.5 ..... *Antrozous pallidus* (Fig. 43)
SI=0.6 ..... *Myotis velifer* (Fig. 25)

17. Each large scale accompanied by single small scale ..... *Diphylla ecaudata* (Fig. 19)
All scales relatively same size 18

18. WI=1.4 ..... *Myotis ciliolabrum* (Fig. 22)
WI<1.4 19

19. Scale maximum d=10µm 20
Scale maximum d<10µm 21

20. Scales with uneven sizes and orientation ..... *Lasiurus ega* (Fig. 31)
Scales are very slanted, one side smooth while other is bumpy ..... *Lasiurus intermedius* (Fig. 32)

21. SI=0.8 ..... *Euderma maculatum* (Fig. 40)
SI<0.8 22

22. SI=0.7 23
SI=0.5 24

23. Scales slanted and even ..... *Lasionycteris noctivagans* (Fig. 35)
Scales rope-like in arrangement, one side smooth while other bumpy ..... *Lasiurus cinereus* (Fig. 30)

24. Scale maximum d<10µm, scales rope-like, smooth ..... *Lasiurus borealis* (Fig. 29)
Scale maximum d<10µm, scales not rope-like 25

25. Scales unevenly shaped and arranged.....*Lasiurus seminolus* (Fig. 33)
Scales uneven with ridges on both sides.....*Nycticeius humeralis* (Fig. 39)

26. SI>2.....*Corynorhinus townsendii* (Fig. 42)
1≤SI<2.....27

27. SI=1.5.....*Pipistrellus hesperus* (Fig. 36)
1≤SI<1.5.....28

28. 1<SI<1.5.....29
SI=1.....30

29. Scale maximum d=10µm.....*Eptesicus fuscus* (Fig. 38)
Scale maximum d=8µm.....*Myotis yumanensis* (Fig. 27)

30. WI=1.5.....*Lasiurus xanthinus* (Fig. 34)
WI<1.5.....31

31. Scales mildly slanted.....*Choeronycteris mexicana* (Fig. 17)
Scales slanted and uneven.....*Pipistrellus* (*Perimyotis*) *subflavus* (Fig. 37)

Family Mormoopidae

***Mormoops megalophylla* - Ghost-faced Bat** (ASNHC 11582)

Medulla not present. Cuticula coronal, serrate, with somewhat even scales. SI=1.1; WI=1.2; scale maximum d=20µm.

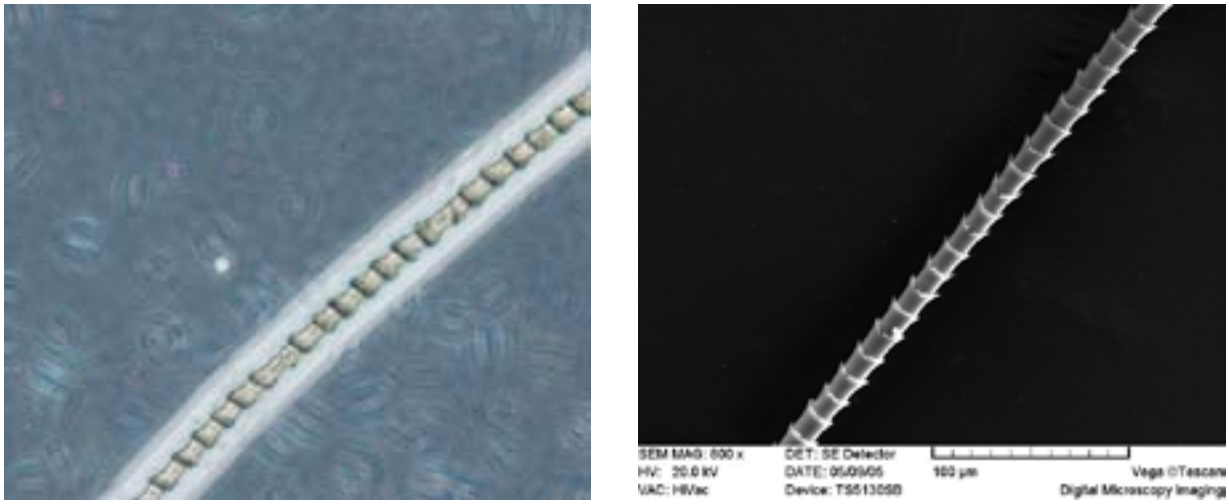

Figure 16. Medulla (left) and cuticula (right) of *Mormoops megalophylla*.

Family Phyllostomidae

***Choeronycteris mexicana* - Mexican Long-tongued Bat** (TTU 44743)

Medulla not present. Cuticula coronal, simple, with mildly slanted scales. SI=1; WI=1; scale maximum d=10μm.

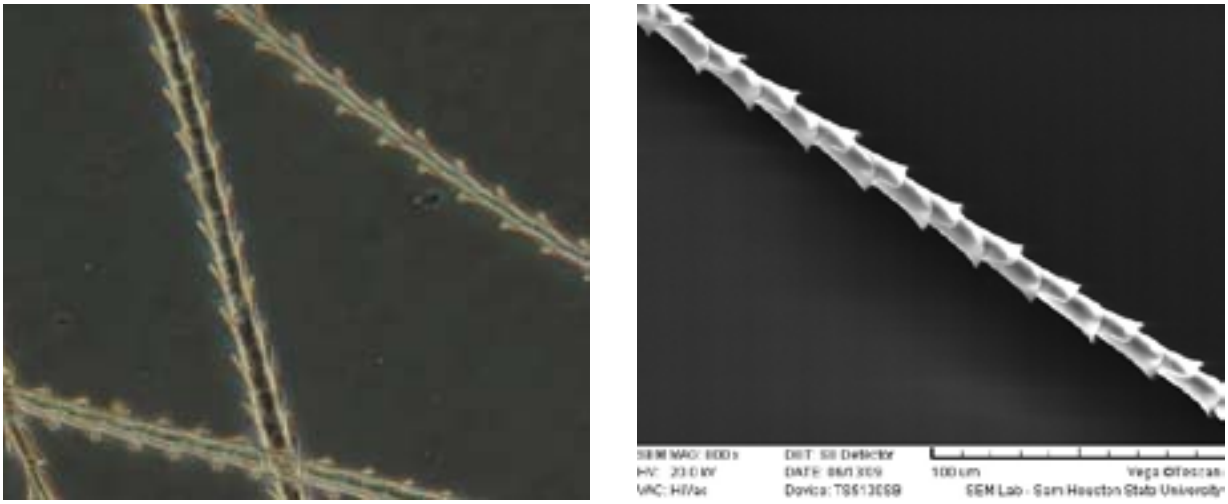

Figure 17. Medulla (left) and cuticula (right) of *Choeronycteris mexicana*.

***Leptonycteris nivalis* - Mexican Long-nosed Bat** (TTU 9208)

Medulla is not present. Cuticula coronal, serrate. Each large scale accompanied by one small scale on each side. SI=0.9; WI=1.5; scale maximum d=20μm.

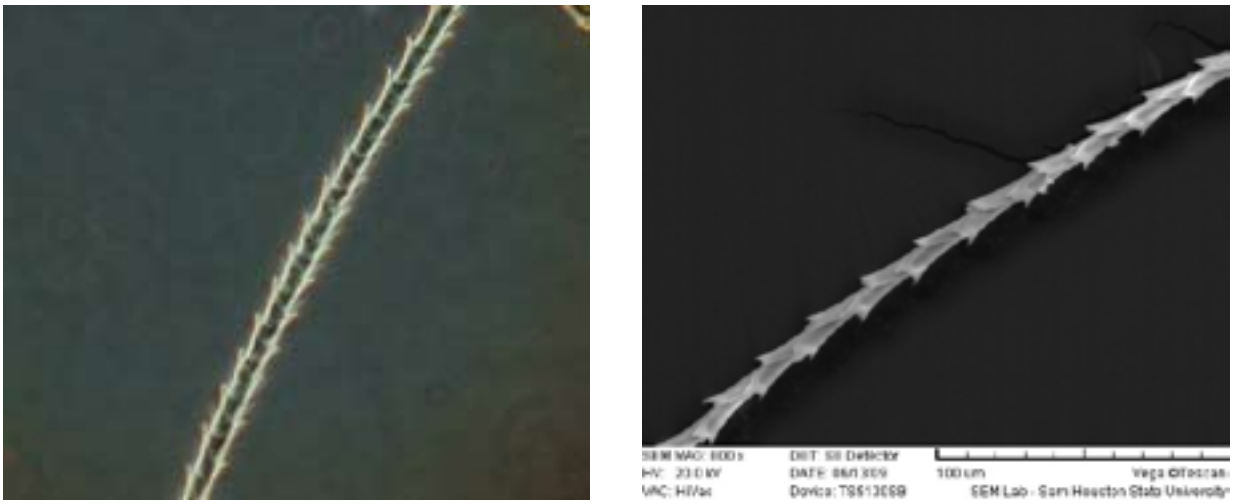

Figure 18. Medulla (left) and cuticula (right) of *Leptonycteris nivalis*.

***Diphylla ecaudata* - Hairy-legged Vampire Bat** (ASNHC 6985)

Medulla not present. Cuticula coronal, simple. Each large scale accompanied by single small scale. SI=0.6; WI=1; scale maximum d=13µm.

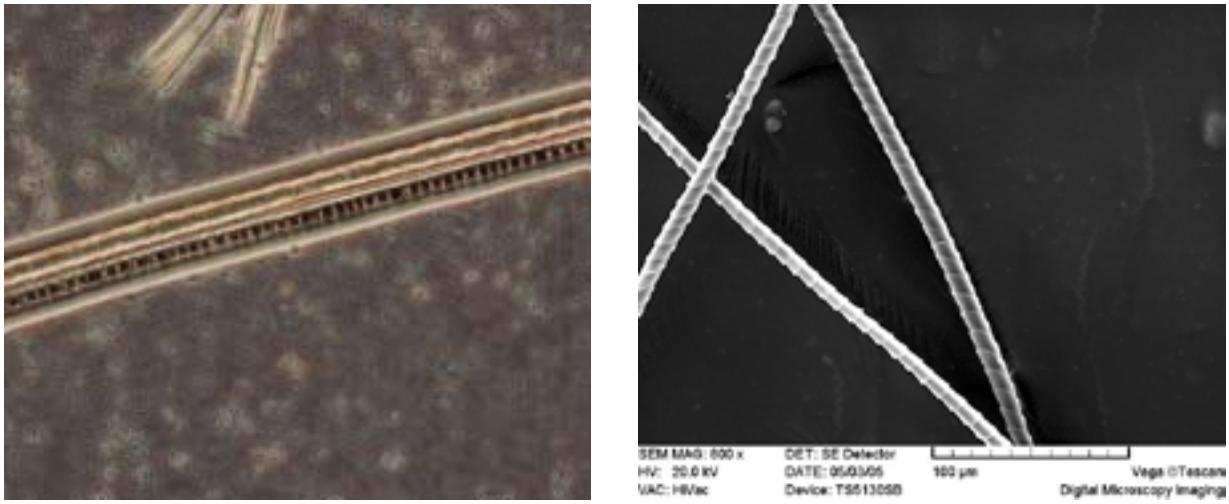

Figure 19. Medulla (left) and cuticula (right) of *Diphylla ecaudata*.

Family Vespertilionidae

***Myotis austroriparius* - Southeastern Myotis** (TTU 29077)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, very uneven in shape and arrangement. SI=0.9; WI=1.5; scale maximum d=10µm.

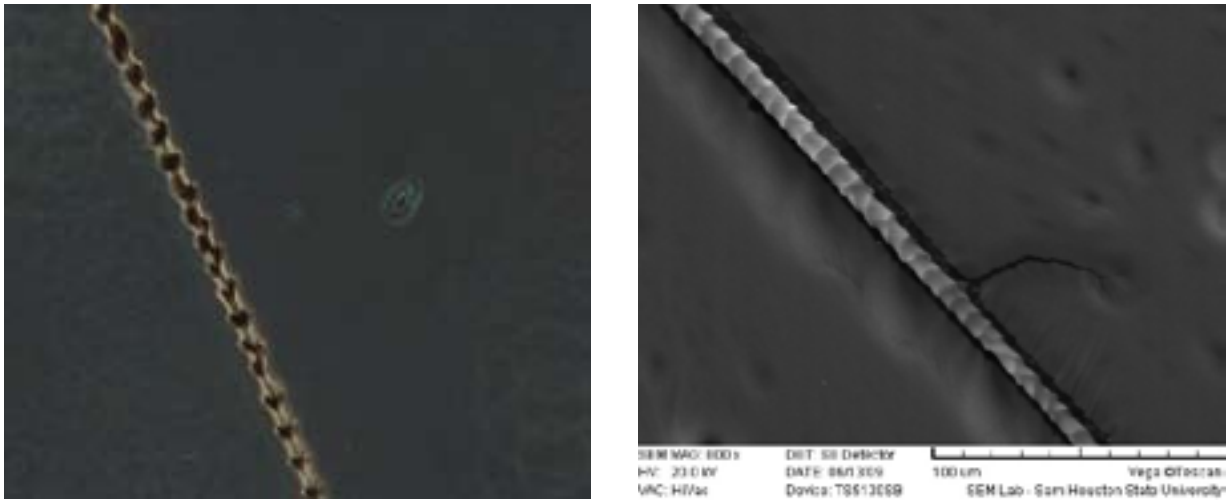

Figure 20. Medulla (left) and cuticula (right) of *Myotis austroriparius*.

***Myotis californicus* - California Myotis** (SHM 194)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, evenly arranged but uneven in shape. SI=0.7; WI=2.1; scale maximum d=10µm.

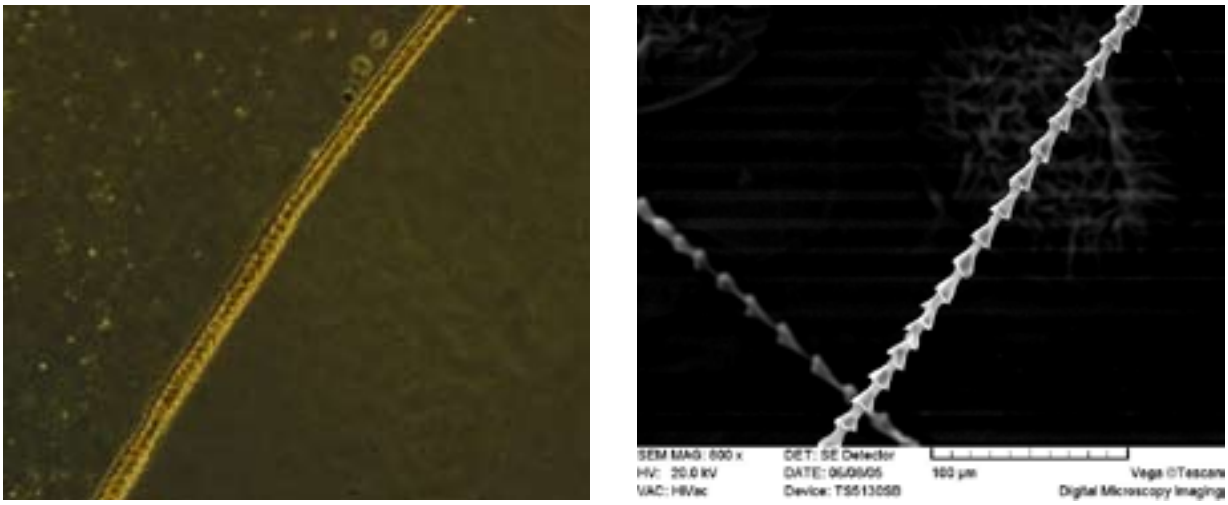

Figure 21. Medulla (left) and cuticula (right) of *Myotis californicus*.

***Myotis ciliolabrum* - Western Small-footed Myotis** (TTU 9151)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, very uneven in shape and arrangement. SI=0.5; WI=1.4; scale maximum d=10µm.

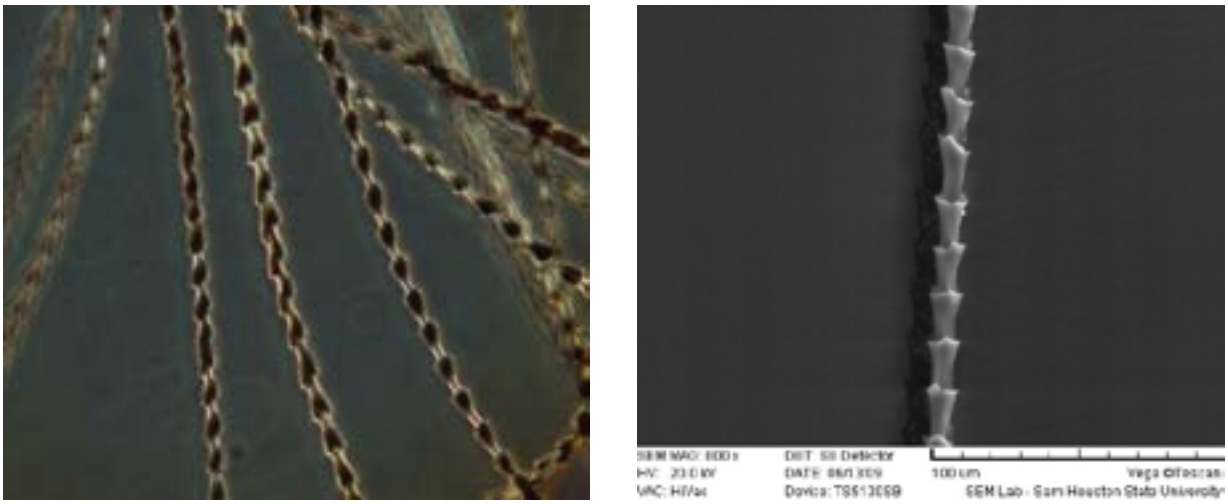

Figure 22. Medulla (left) and cuticula (right) of *Myotis ciliolabrum*.

***Myotis septentrionalis* - Northern Long-eared Myotis** (TCWC 28746)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, of uneven size and arrangement in some places. SI=0.4; WI=2; scale maximum d=7µm.

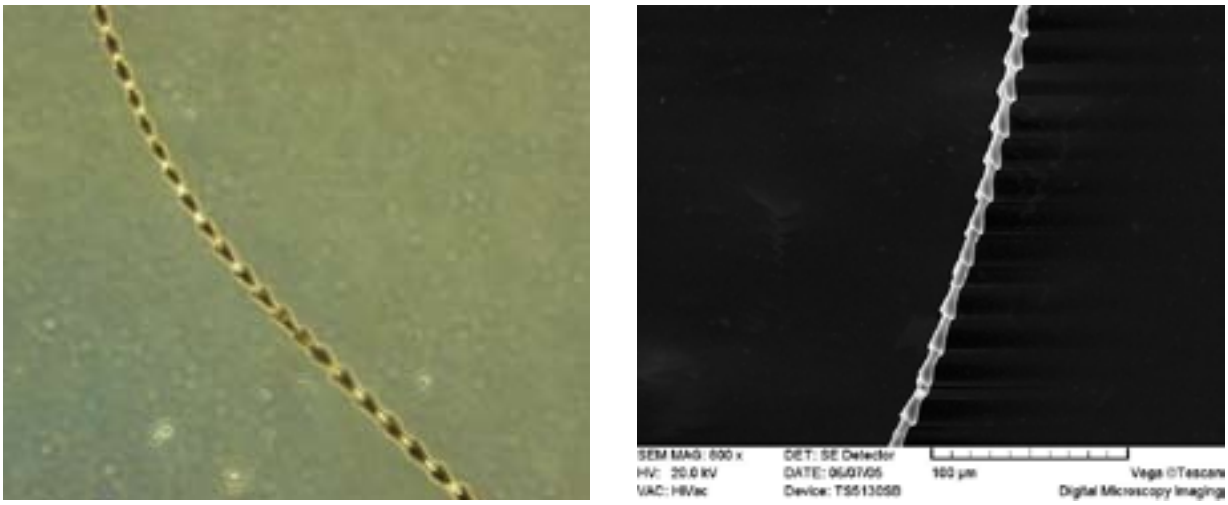

Figure 23. Medulla (left) and cuticula (right) of *Myotis septentrionalis*.

***Myotis thysanodes* - Fringed Myotis** (SHM 921)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, even in shape and uneven in arrangement. SI=0.7; WI=1.5; scale maximum d=10µm.

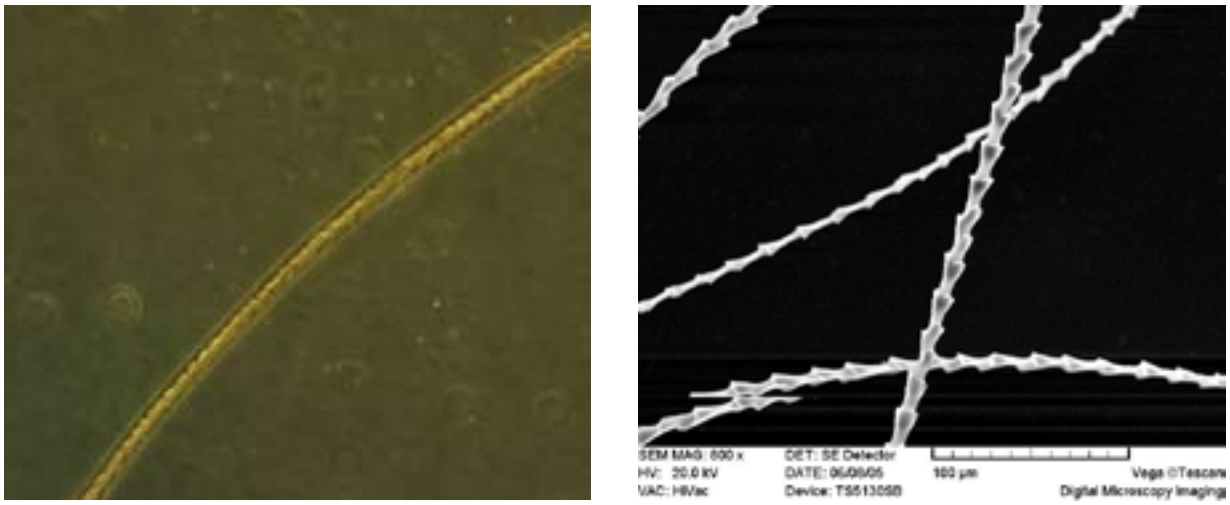

Figure 24. Medulla (left) and cuticula (right) of *Myotis thysanodes*.

***Myotis velifer* - Cave Myotis** (SHM 138)

Medulla not present. Cuticula coronal, simple. Scales funnel-like and even. SI=0.6; WI=1.5; scale maximum d=10µm.

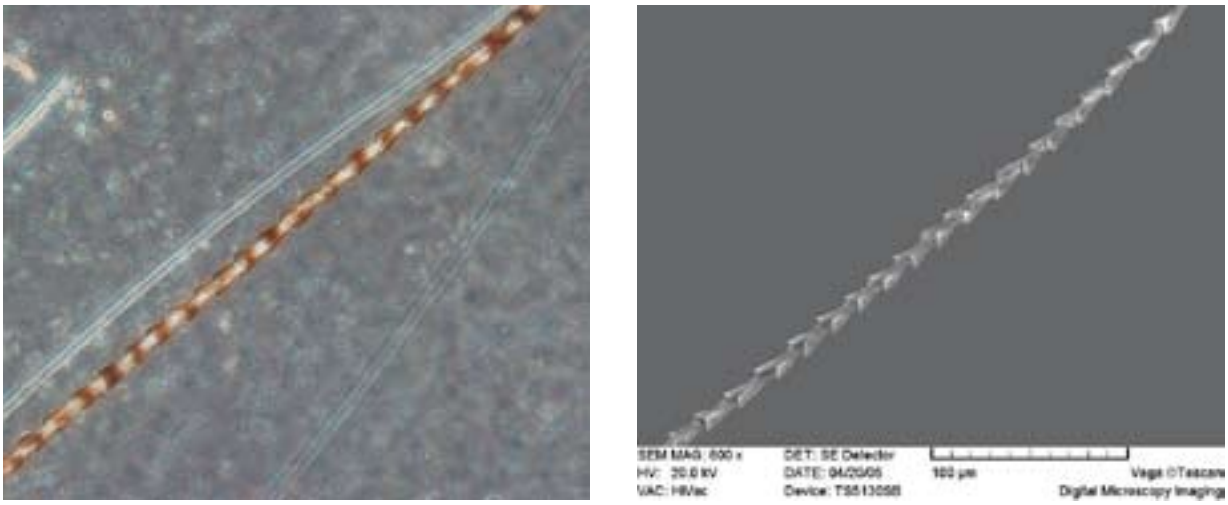

Figure 25. Medulla (left) and cuticula (right) of *Myotis velifer*.

***Myotis volans* - Long-legged Myotis** (ASNHC 12237)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, somewhat even. SI=0.5; WI=2; scale maximum d=7µm.

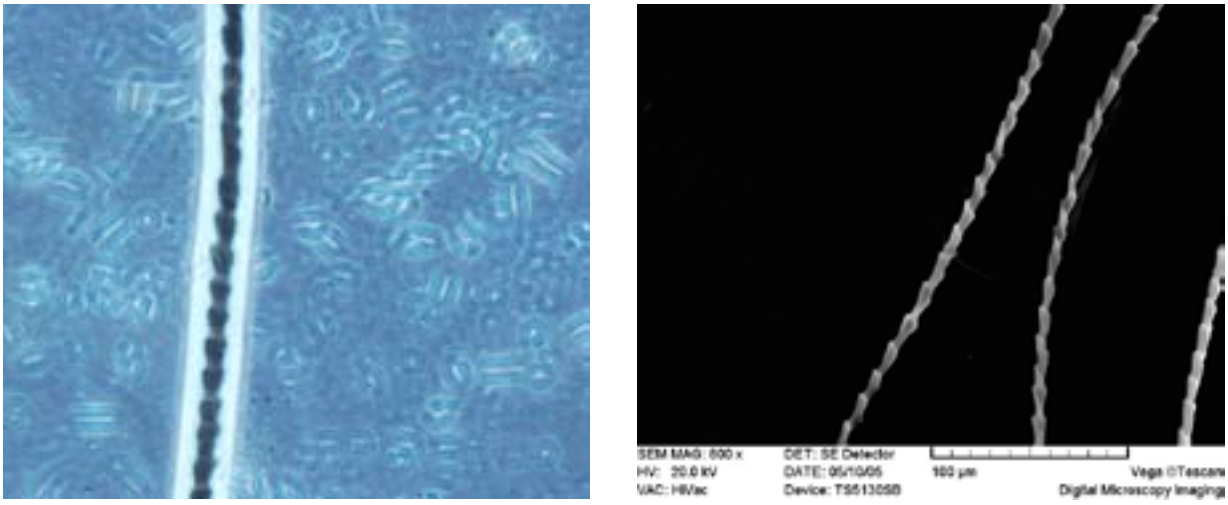

Figure 26. Medulla (left) and cuticula (right) of *Myotis volans*.

***Myotis yumanensis* - Yuma Myotis** (ASNHC 11584)

Medulla not present. Cuticula coronal, simple. Scales flat to funnel-like, uneven. SI=1.1; WI=1; scale maximum d=8μm.

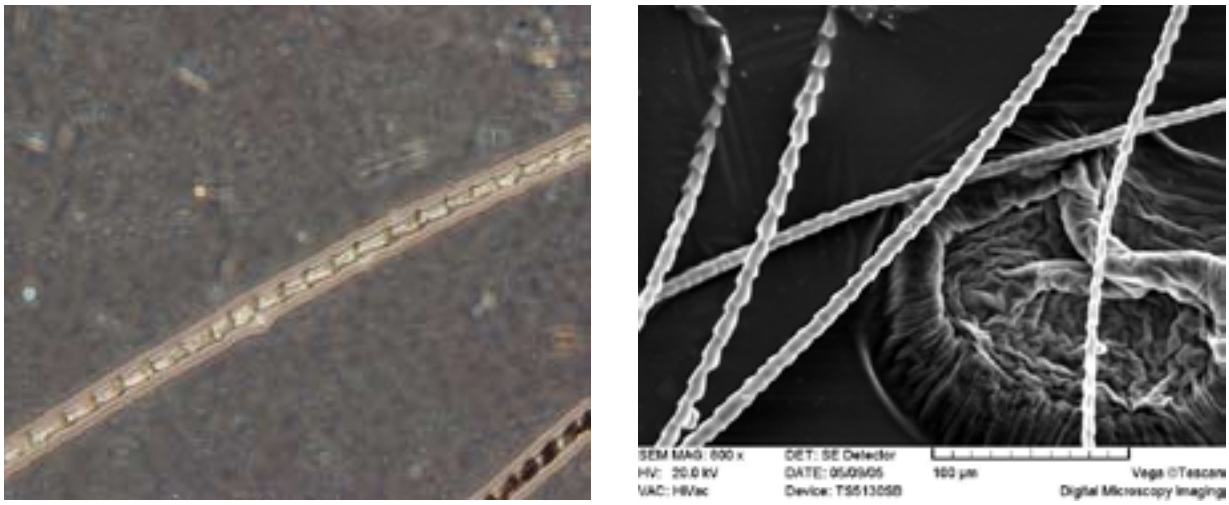

Figure 27. Medulla (left) and cuticula (right) of *Myotis yumanensis*.

***Lasiurus blossevillii* - Western Red Bat** (TCWC 56772)

Medulla not present. Cuticula coronal, simple. Scales funnel-like, uneven. SI=0.7; WI=1.5; scale maximum d=10μm.

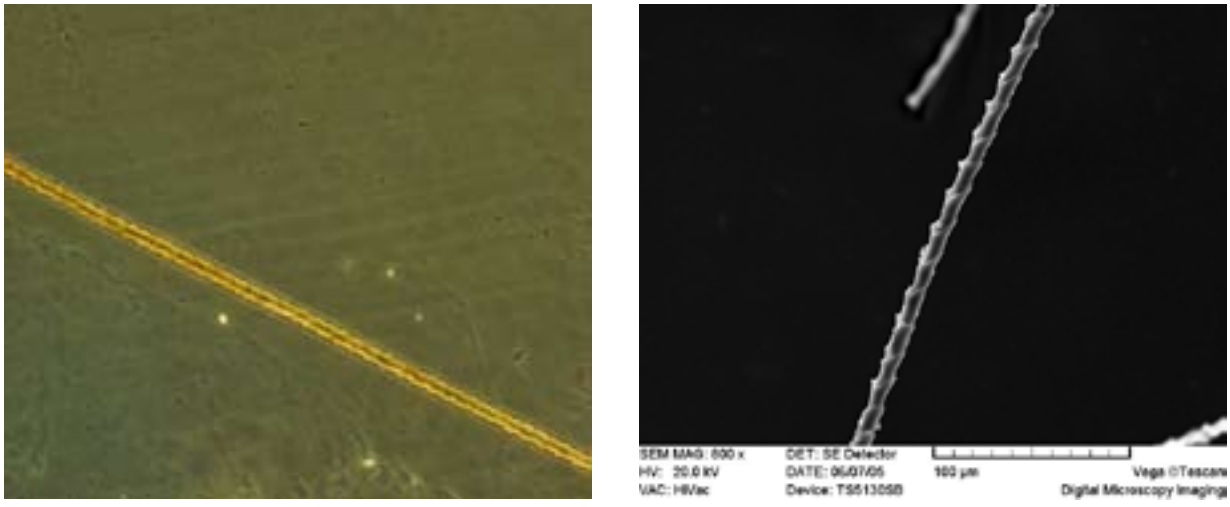

Figure 28. Medulla (left) and cuticula (right) of *Lasiurus blossevillii*.

***Lasiurus borealis* - Eastern Red Bat** (SHM 29)

Medulla not present. Cuticula coronal, simple. Scale arrangement rope-like, almost completely smooth. SI=0.5; WI=1; scale maximum d=7µm.

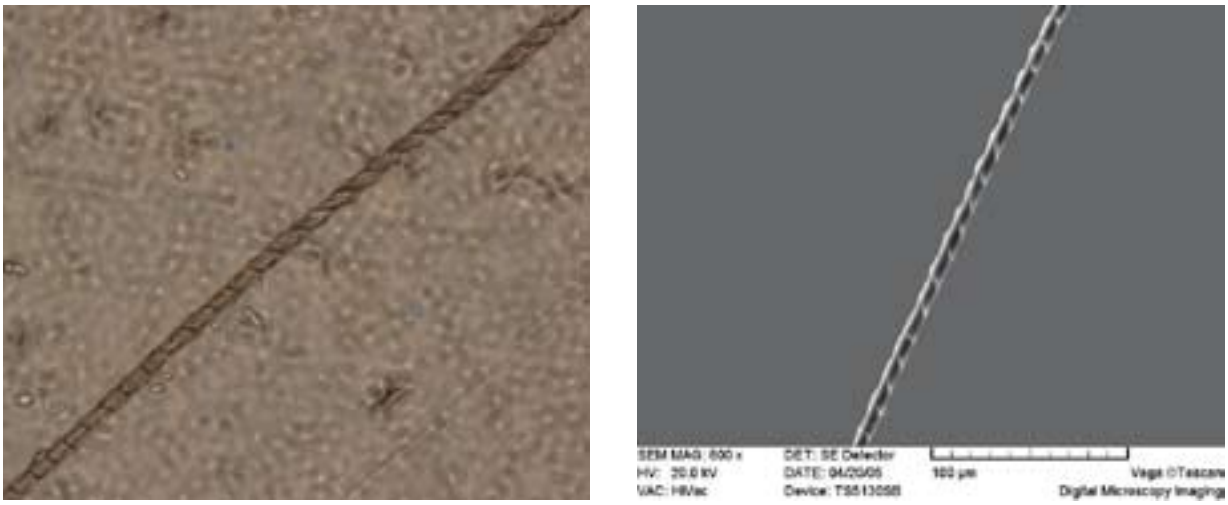

Figure 29. Medulla (left) and cuticula (right) of *Lasiurus borealis*.

***Lasiurus cinereus* - Hoary Bat** (SHM 196)

Medulla not present. Cuticula coronal, simple. Scale arrangement rope-like, one side smooth and other bumpy. SI=0.7; WI=1.1; scale maximum d=7µm.

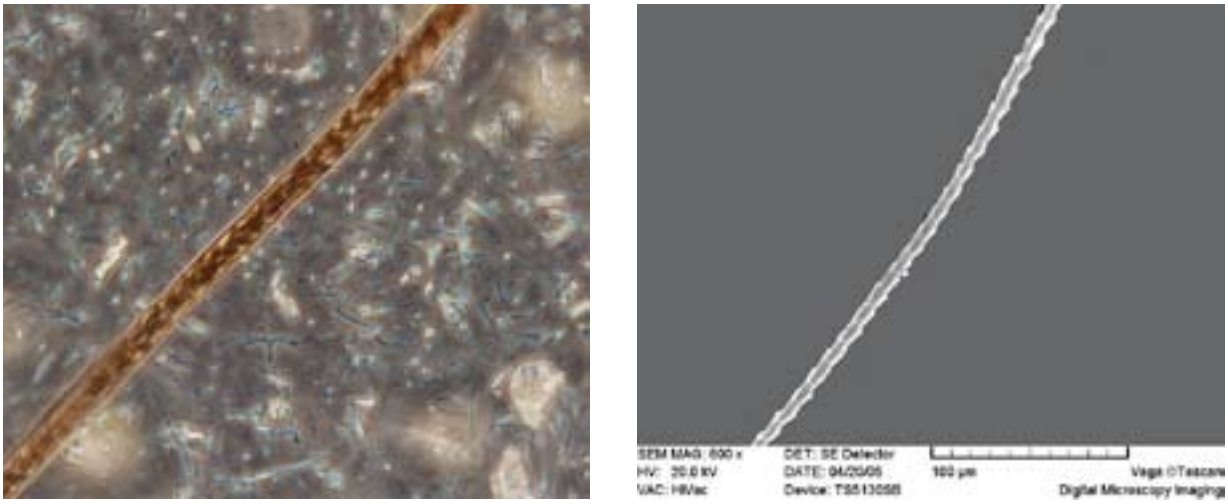

Figure 30. Medulla (left) and cuticula (right) of *Lasiurus cinereus*.

***Lasiurus ega* - Southern Yellow Bat** (ASNHC 6994)

Medulla not present. Cuticula coronal, simple. Scales with uneven sides and orientation. SI=0.8; WI=1; scale maximum d=10µm.

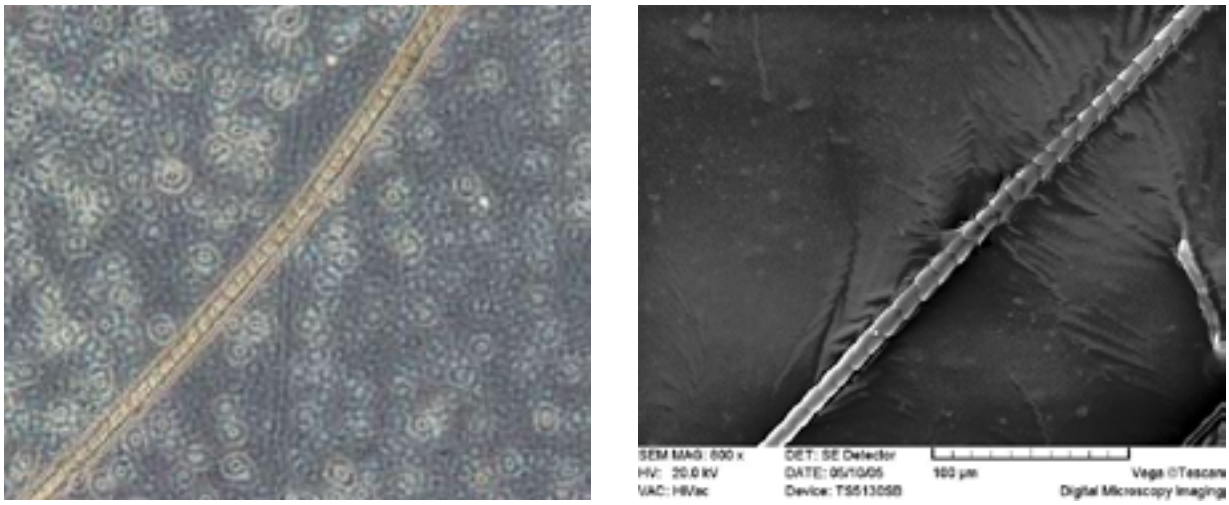

Figure 31. Medulla (left) and cuticula (right) of *Lasiurus ega*.

***Lasiurus intermedius* - Northern Yellow Bat** (ASNHC 1409)

Medulla not present. Cuticula coronal, simple. Scales very slanted, one side smooth and other side bumpy. SI=0.7; WI=1; scale maximum d=10µm.

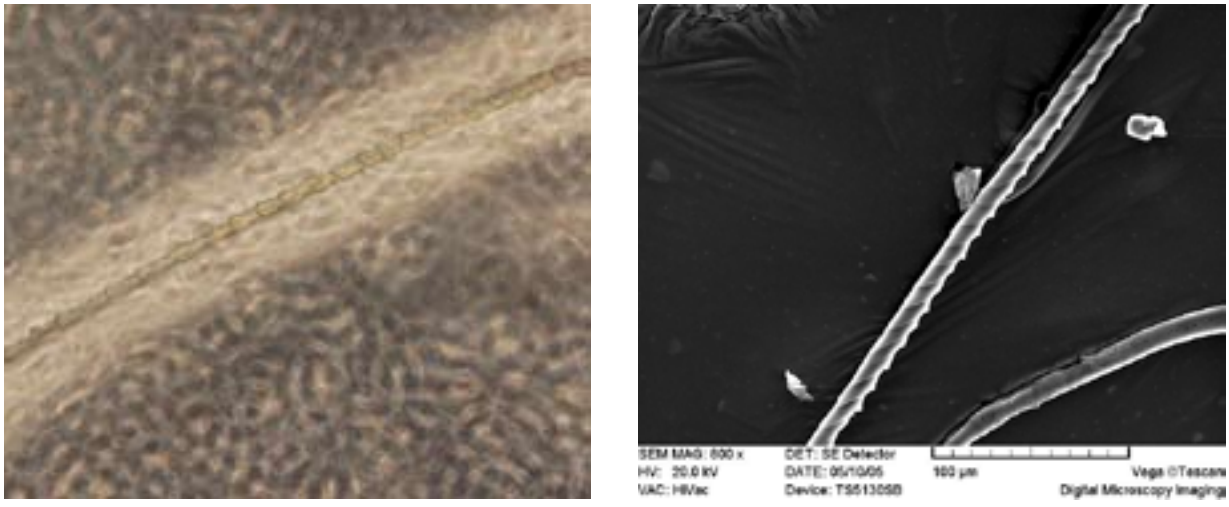

Figure 32. Medulla (left) and cuticula (right) of *Lasiurus intermedius*.

***Lasiurus seminolus* - Seminole Bat** (SHM 227)

Medulla not present. Cuticula coronal, simple. Scales uneven in shape and arrangement. SI=1.1; WI=1.2; scale maximum d=20µm.

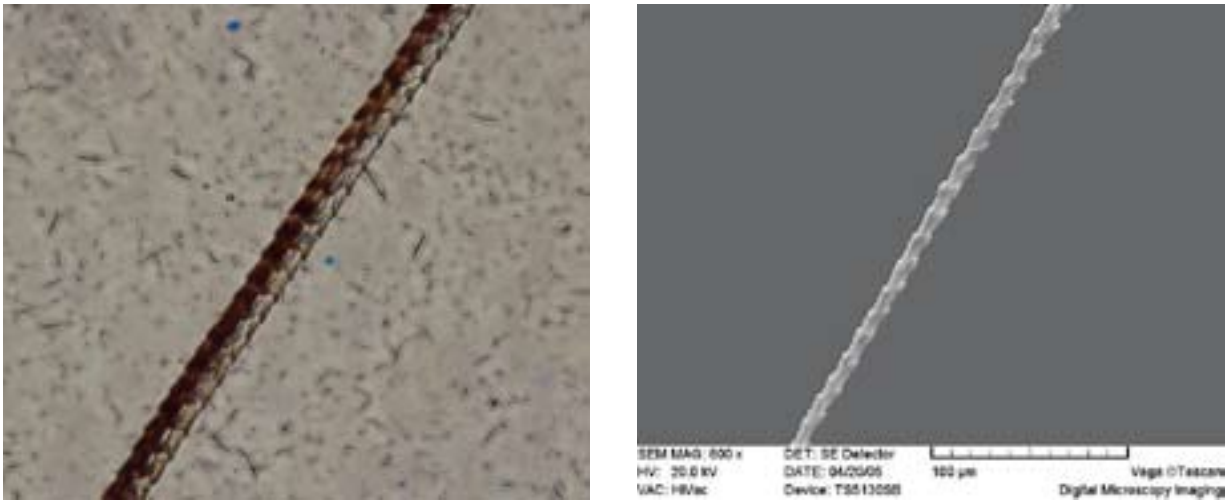

Figure 33. Medulla (left) and cuticula (right) of *Lasiurus seminolus*.

***Lasiurus xanthinus* - Western Yellow Bat** (ASNHC 11506)

Medulla not present. Cuticula coronal, simple. Scales of uneven size and arrangement. SI=1; WI=1.5; scale maximum d=8µm.

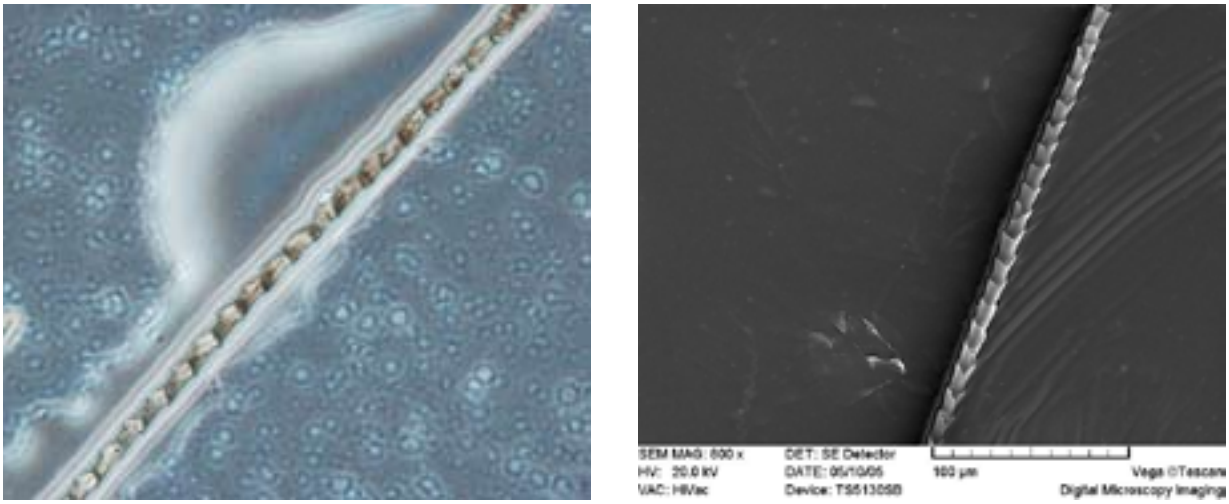

Figure 34. Medulla (left) and cuticula (right) of *Lasiurus xanthinus*.

***Lasionycteris noctivagans* - Silver-haired Bat** (ASNHC 12898)

Medulla not present. Cuticula coronal, simple. Scales slanted and even. SI=0.7; WI=1; scale maximum d=7µm.

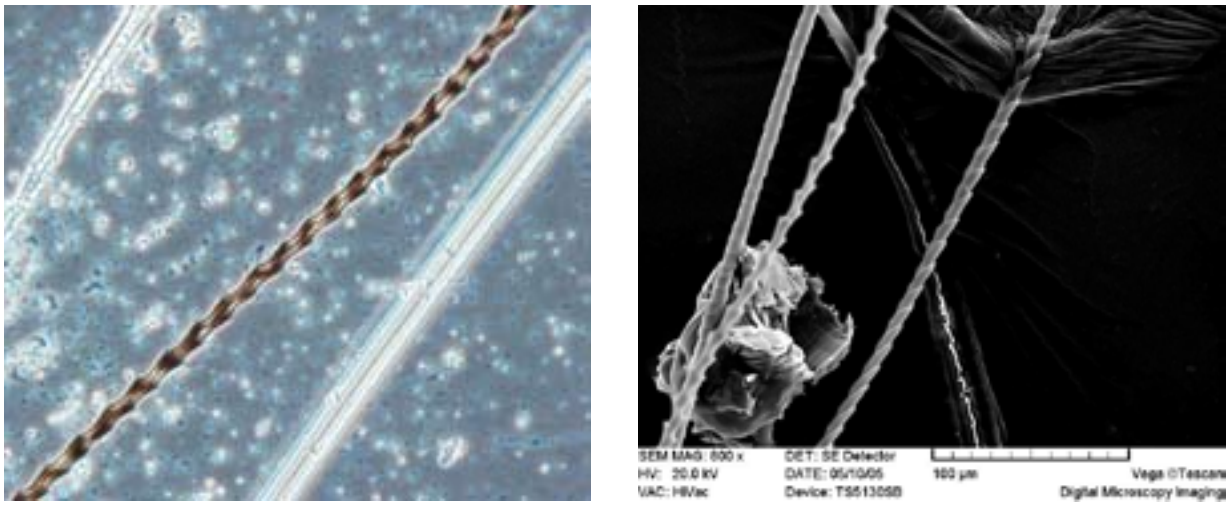

Figure 35. Medulla (left) and cuticula (right) of *Lasionycteris noctivagans*.

***Pipistrellus hesperus* - Western Pipistrelle** (ASNHC 9161)

Medulla not present. Cuticula coronal, simple. Scales slanted and uneven. SI=1.5; WI=1; scale maximum d=10µm.

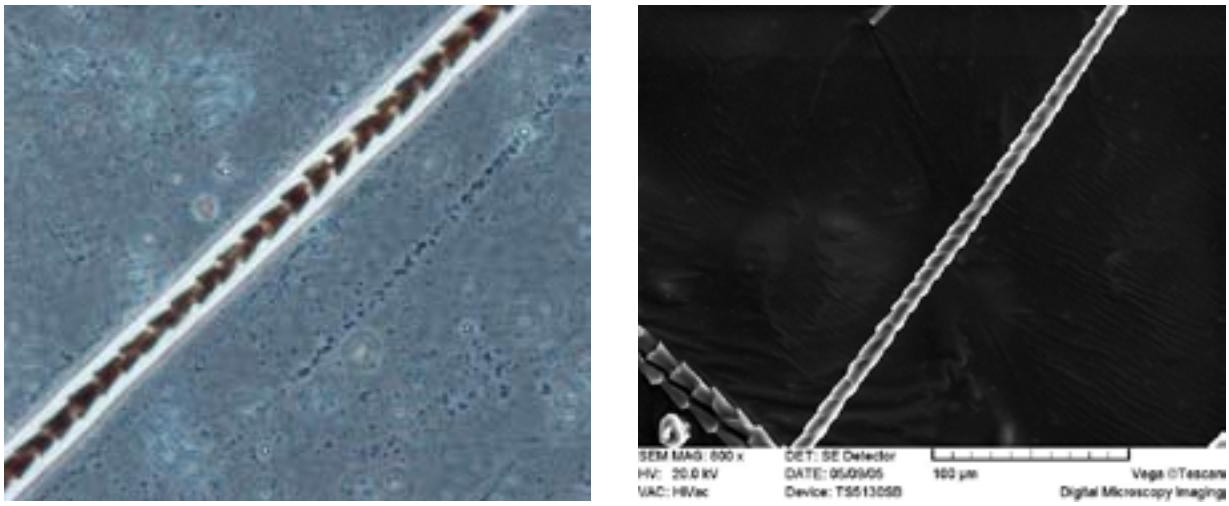

Figure 36. Medulla (left) and cuticula (right) of *Pipistrellus hesperus*.

***Pipistrellus* (*Perimyotis*) *subflavus* - Eastern Pipistrelle** (SHM 395)

Medulla not present. Cuticula coronal, simple. Scales slanted and even. SI=1; WI=1; scale maximum d=10µm.

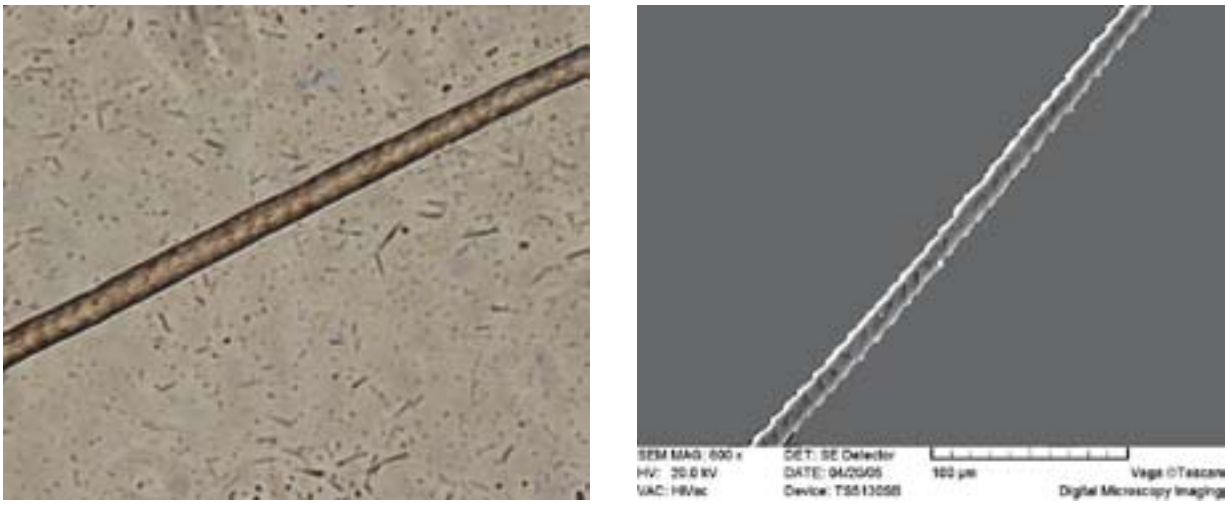

Figure 37. Medulla (left) and cuticula (right) of *Pipistrellus* (*Perimyotis*) *subflavus*.

***Eptesicus fuscus* - Big Brown Bat** (SHM 902)

Medulla not present. Cuticula coronal, simple. Scales have indented wider part, not all equal. SI=1.2; WI=1; scale maximum d=10µm.

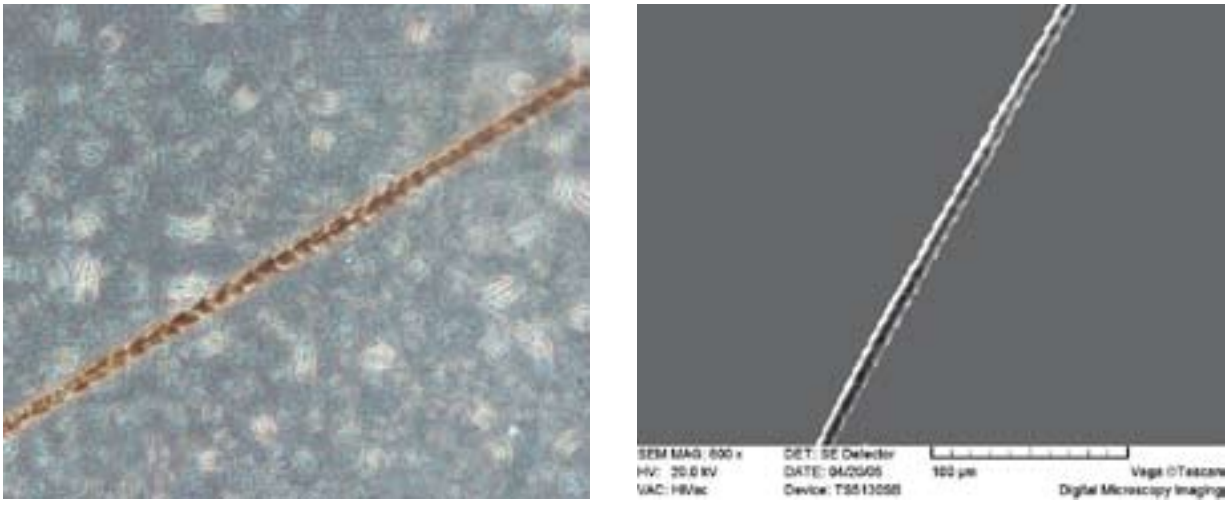

Figure 38. Medulla (left) and cuticula (right) of *Eptesicus fuscus*.

***Nycticeius humeralis* - Evening Bat** (SHM 228)

Medulla not present. Cuticula coronal, simple. Scales uneven with ridges on both sides. SI=0.5; WI=1; scale maximum d=7µm.

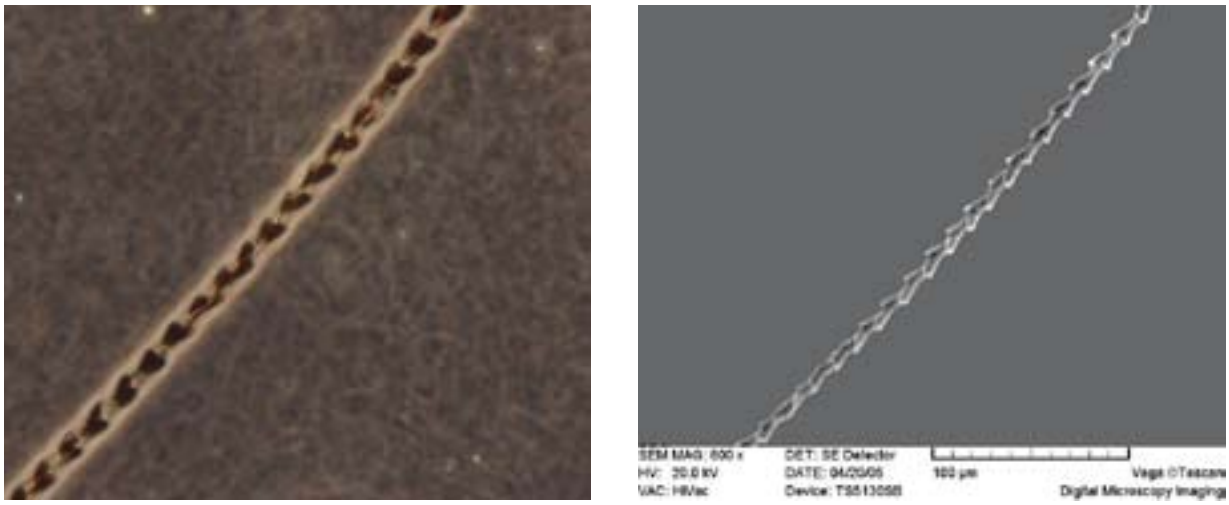

Figure 39. Medulla (left) and cuticula (right) of *Nycticeius humeralis*.

***Euderma maculatum* - Spotted Bat** (TCWC 26538)

Medulla not present. Cuticula coronal, simple. Scales slanted and uneven. SI=0.8; WI=1; scale maximum d=8µm.

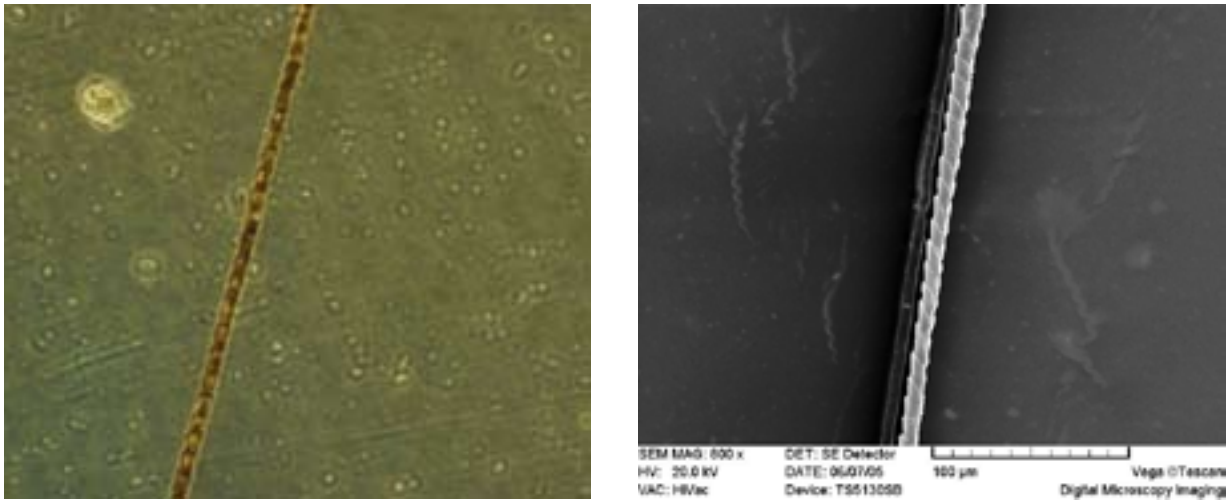

Figure 40. Medulla (left) and cuticula (right) of *Euderma maculatum*.

***Corynorhinus rafinesquii* - Rafinesque's Big-eared Bat** (TTU 45393)

Medulla not present. Cuticula coronal, simple. Scales funnel-shaped, slanted and uneven. SI=0.9; WI=2.1; scale maximum d=13µm.

Figure 41. Medulla (left) and cuticula (right) of *Corynorhinus rafinesquii*.

***Corynorhinus townsendii* - Townsend's Big-eared Bat** (ASNHC 11586)

Medulla not present. Cuticula coronal, simple. Scales very slanted and close to each other. SI=2.5; WI=1; scale maximum d=8µm.

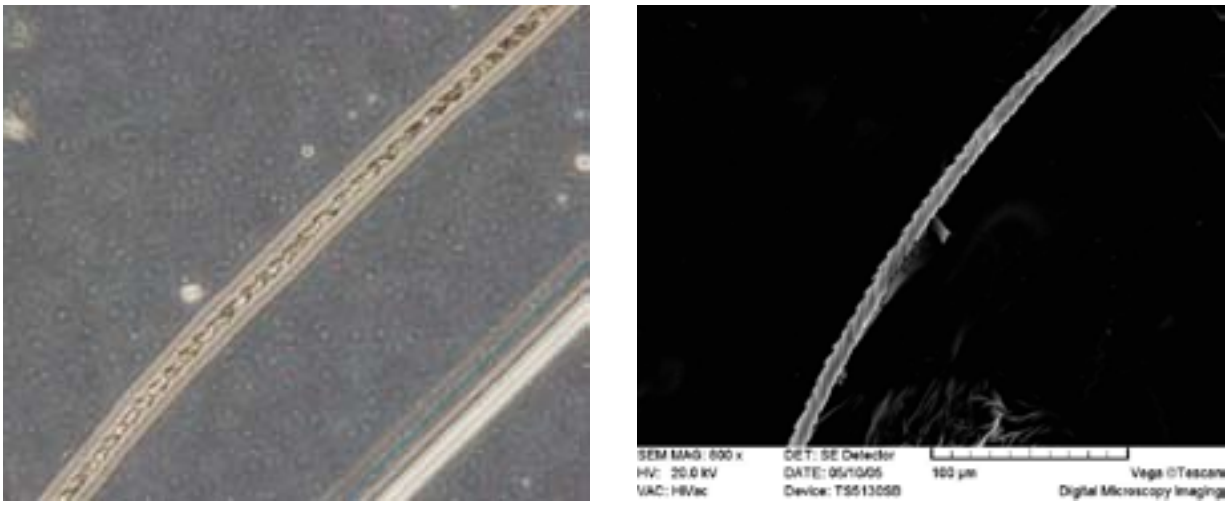

Figure 42. Medulla (left) and cuticula (right) of *Corynorhinus townsendii*.

***Antrozous pallidus* - Pallid Bat** (SHM 195)

Medulla not present. Cuticula coronal, simple. Scales funnel-shaped, spirally arranged. SI=0.5; WI=1.5; scale maximum d=10µm.

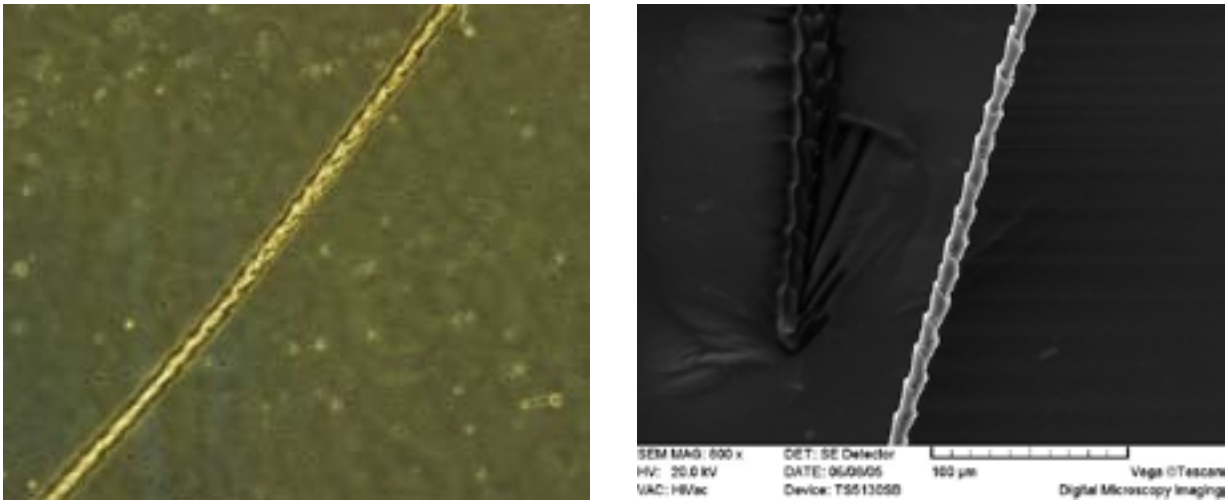

Figure 43. Medulla (left) and cuticula (right) of *Antrozous pallidus*.

Family Molossidae

***Tadarida brasiliensis* - Brazilian Free-tailed Bat** (SHM 167)

Medulla not present. Cuticula coronal, dentate. Scales have average of 6 very large indentations, with middle one the largest. SI=1.1; WI=1.3; scale maximum d=16µm.

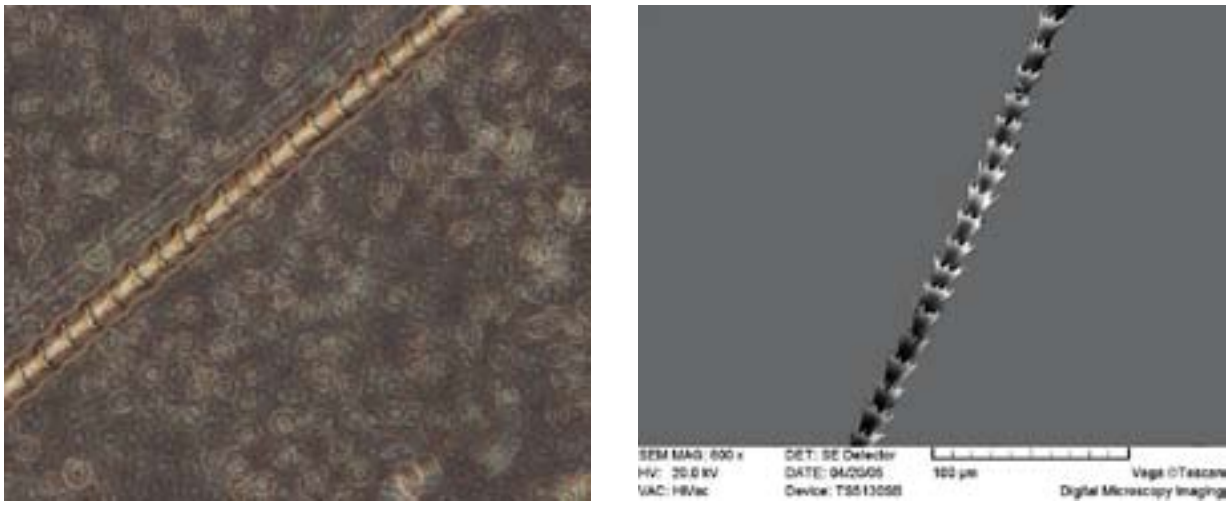

Figure 44. Medulla (left) and cuticula (right) of *Tadarida brasiliensis*.

***Nyctinomops femorosaccus* - Pocketed Free-tailed Bat** (ASNHC 11529)

Medulla not present. Cuticula coronal, dentate. Scales have average of 8 indentations that are small and even. SI=1.5; WI=3; scale maximum d=20µm.

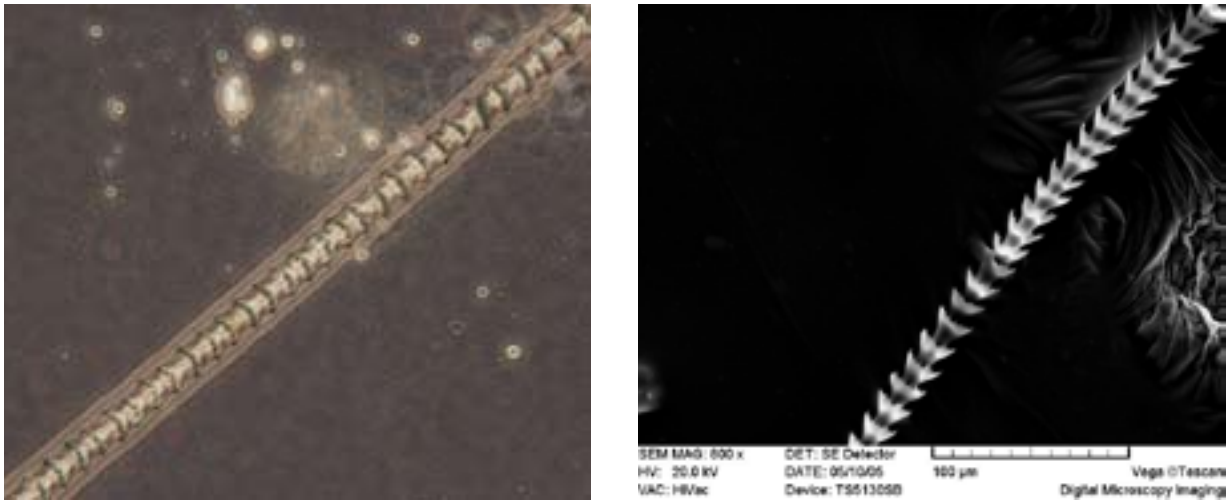

Figure 45. Medulla (left) and cuticula (right) of *Nyctinomops femorosaccus*.

***Nyctinomops macrotis* - Big Free-tailed Bat** (ASNHC 11588)

Medulla not present. Cuticula coronal, dentate. Scales have average of 8 indentations that are small and even. SI=1.5; WI=1.3; scale maximum d=13µm.

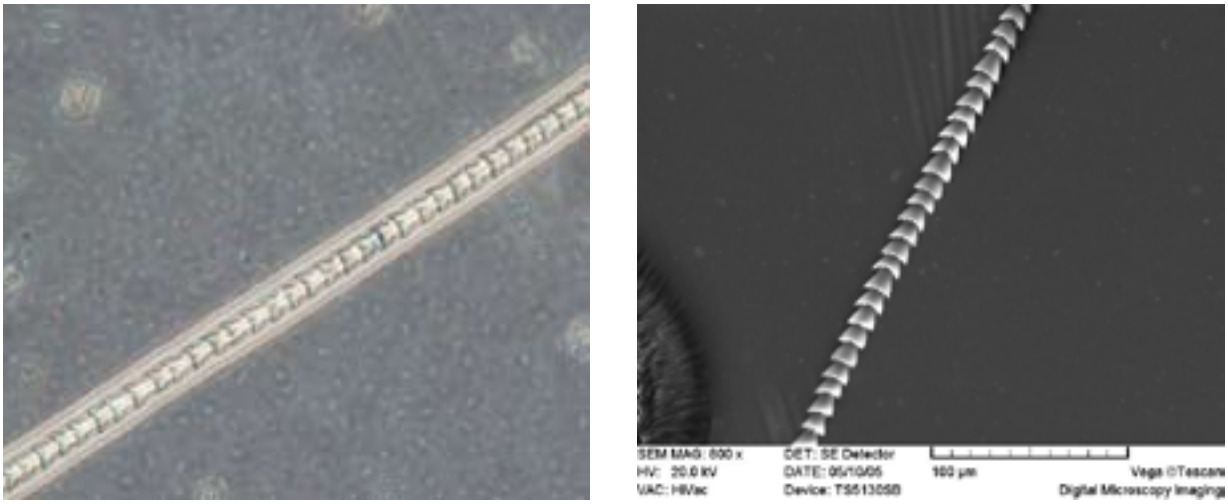

Figure 46. Medulla (left) and cuticula (right) of *Nyctinomops macrotis*.

***Eumops perotis* - Western Mastiff Bat** (ASNHC 11527)

Medulla not present. Cuticula coronal, dentate. Scales have average of 8 indentations that are small and mostly of same size. SI=1.2; WI=1.3; scale maximum d=13µm.

Figure 47. Medulla (left) and cuticula (right) of *Eumops perotis*.

ORDER CARNIVORA – CARNIVORES

The medulla in all Carnivora is vacuolated to some degree.

1. Medulla discontinuous, compound (Fig. 3).....*Spilogale gracilis* (Fig. 64)
   Medulla continuous.....2

2. Medulla homogeneous (Fig. 6).....3
   Medulla nodose (Fig. 5).....11

3. Medulla not penetrated.....4
   Medulla penetrated.....5

4. Medulla not completely penetrated.....*Canis latrans* (Fig. 48)
   Medulla not penetrated or mixed homogeneous type a and b (Fig. 6).....*Panthera onca* (Fig. 74)

5. Medulla homogeneous type a (Fig. 6).....6
   Medulla homogeneous type b (Fig. 6).....7

6. Cuticula imbricate, flattened (Fig. 7e), scales form wavy disturbed rows.....*Conepatus leuconotus* (Fig. 68)
   Cuticula imbricate, undefined, scales wavy where present.....*Taxidea taxus* (Fig. 62)

7. Medulla occupies more than 1/2 of shaft.....8
   Medulla occupies entire shaft.....9

8. Cuticula imbricate, flattened (Fig. 7e), scales form wavy regular rows, shaft d=133µm.....*Canis lupus* (Fig. 49)
   Cuticula imbricate, flattened (Fig. 7e), scales form wavy irregular rows,
   shaft d=125µ.....*Mephitis mephitis* (Fig. 67)

9. Cuticula flattened (Fig. 7e), shaft d=140µm.....*Mephitis macroura* (Fig. 66)
   Cuticula crenate (Fig. 7d).....10

10. Shaft d<100µm.....*Vulpes vulpes* (Fig. 52)
    Shaft d>100µm.....*Canis rufus* (Fig. 50)

11. Medulla unordered and undisturbed, cuticula imbricate, flattened (Fig. 7e).....*Urocyon cinereoargenteus* (Fig. 53)
Medulla continuous, nodose type a (Fig. 5).....12

12. Medulla occupies entire shaft.....13
Medulla occupies less than entire shaft.....14

13. Scales smooth and form wavy rows, shaft d>130µm.....*Herpailurus yaguarondi* (Fig. 72)
Scales and rows wavy, shaft d<80µm.....*Lynx rufus* (Fig. 73)

14. Medulla occupies more than 1/2 but less than entire shaft.....15
Medulla occupies ≤1/2 of shaft.....23

15. Cuticula crenate (Fig. 7d).....16
Cuticula flattened (Fig. 7e).....18

16. Shaft d>100µm.....*Vulpes velox* (Fig. 51)
Shaft d<100µm.....17

17. Very large vacuoles appear occasionally, scales not always visible.....*Mustela nigripes* (Fig. 60)
Scales and rows wavy.....*Nasua narica* (Fig. 58)

18. Shaft d≥100µm.....19
Shaft d<100µm.....20

19. Scales wavy but do not form real rows.....*Puma concolor* (Fig. 69)
Vacuoles flattened, scales form extremely close and wavy rows.....*Mustela vison* (Fig. 61)

20. Vacuoles flattened.....*Mustela frenata* (Fig. 59)
Vacuoles not flattened.....21

21. Shaft 80<d<100µm.....*Spilogale putorius* (Fig. 65)
Shaft d<80µm.....22

22. Scales and rows wavy and sometimes disturbed, shaft d=64µm.....*Leopardus pardalis* (Fig. 70)
Scales wavy and very close, shaft d=73µm.....*Bassariscus astutus* (Fig. 56)

23. Medulla occupies 1/2 of the shaft.....24
Medulla occupies 1/3 of the shaft.....25

24. Cuticula flattened (Fig. 7e).....*Procyon lotor* (Fig. 57)
Cuticula crenate (Fig. 7d).....*Ursus americanus* (Fig. 54)

25. Medulla made of large square "cells", shaft d=55µm.....*Leopardus wiedii* (Fig. 71)
Medulla not made of large square "cells".....26

26. Shaft d=162µm.....*Lontra canadensis* (Fig. 63)
Shaft d=160µm.....*Ursus arctos* (Fig. 55)

Family Canidae

***Canis latrans* - Coyote** (SHM 53)

Medulla continuous, homogeneous but unpenetrated by light, vacuolated, occupies entire shaft. Cuticula imbricate, crenate, scale edges smooth, rows very irregular and broken. Midshaft dia. 105 µm.

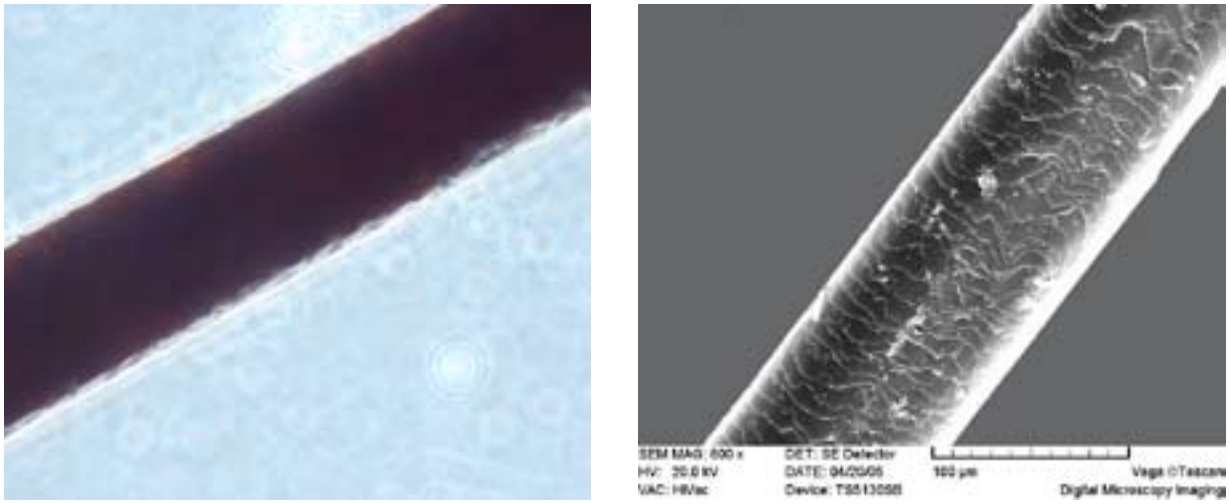

Figure 48. Medulla (left) and cuticula (right) of *Canis latrans*.

***Canis lupus* - Gray Wolf** (TCWC 20852)

Medulla continuous, homogeneous type b, disturbed with vacuoles, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, with wavy scales and regular rows. Midshaft dia. 133µm.

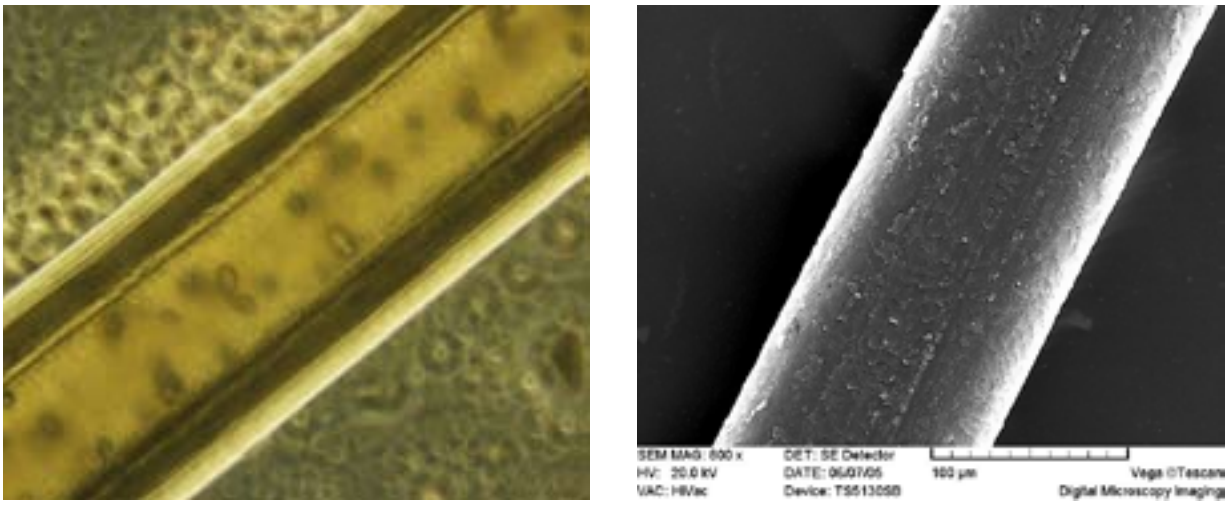

Figure 49. Medulla (left) and cuticula (right) of *Canis lupus*.

***Canis rufus* - Red Wolf** (TCWC 6541)

Medulla continuous, homogeneous type b, vacuolated, occupies entire shaft. Cuticula imbricate, crenate, wavy edges of scales with mosaic arrangement. Midshaft dia. 133µm.

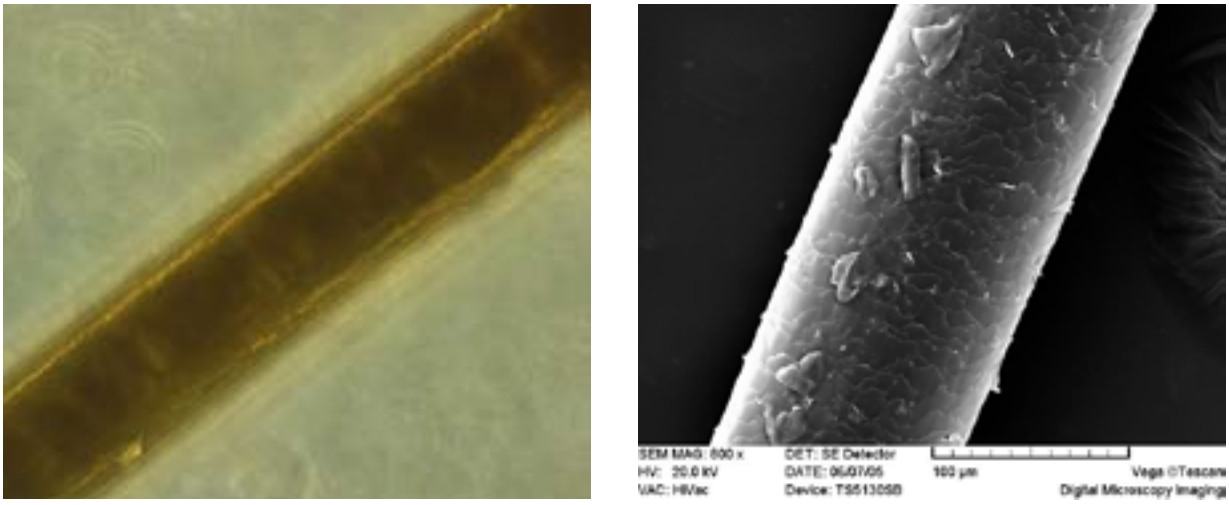

Figure 50. Medulla (left) and cuticula (right) of *Canis rufus*.

***Vulpes velox* - Swift or Kit Fox** (SHM 174)

Medulla continuous, nodose type a, heavily vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, crenate, scales smooth and tall, rows irregular. Midshaft dia. 130µm.

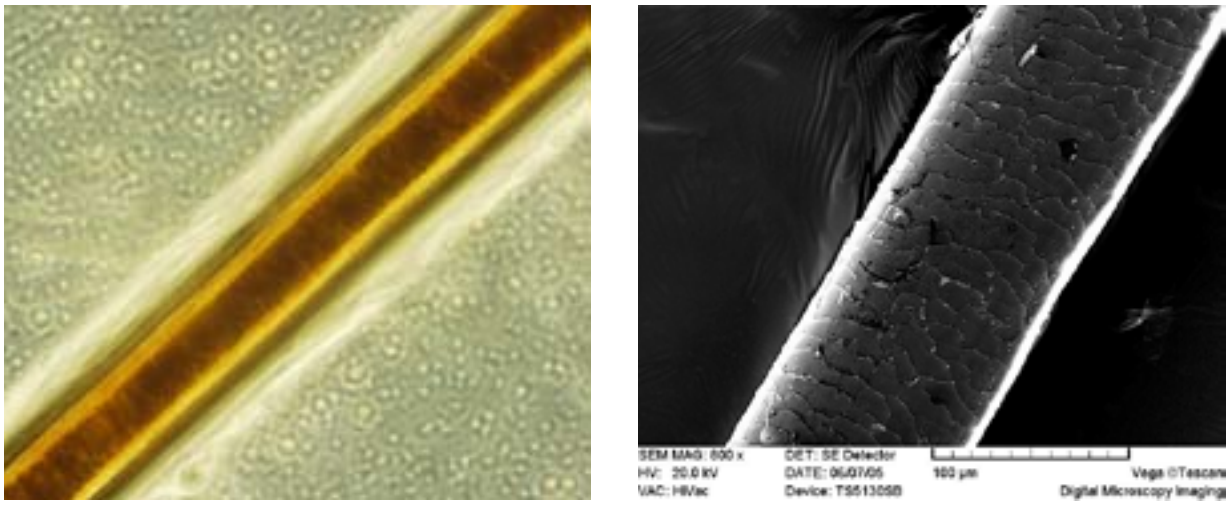

Figure 51. Medulla (left) and cuticula (right) of *Vulpes velox*.

***Vulpes vulpes* - Red Fox** (ASNHC 1018)

Medulla continuous, homogeneous type b, disturbed by vacuoles, occupies entire shaft. Cuticula imbricate, crenate, with irregular rows. Midshaft dia. 82µm.

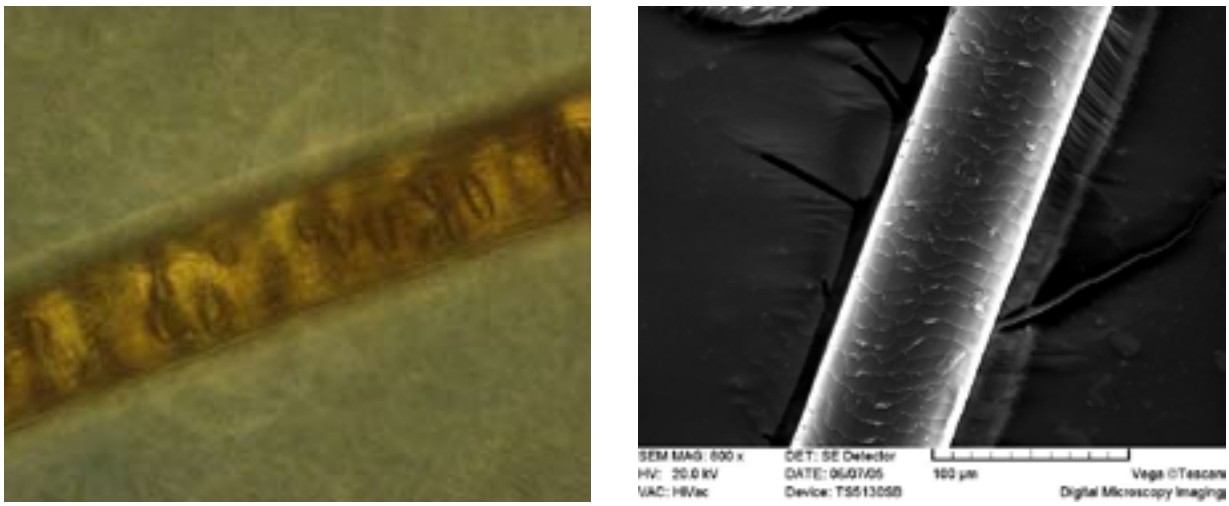

Figure 52. Medulla (left) and cuticula (right) of *Vulpes vulpes*.

***Urocyon cinereoargenteus* - Common Gray Fox** (SHM 268)

Medulla continuous, nodose type b, unordered, undisturbed, flattened "cells", occupies more than 1/2 of shaft. Cuticula imbricate, flattened, with smooth scales. Midshaft dia. 140µm.

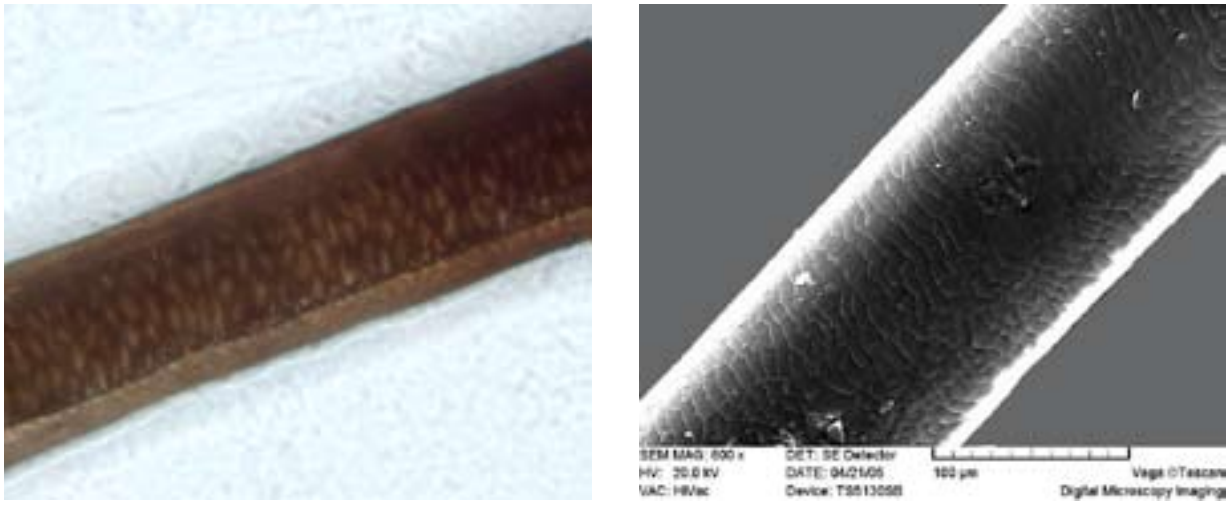

Figure 53. Medulla (left) and cuticula (right) of *Urocyon cinereoargenteus*.

Family Ursidae

***Ursus americanus* - American Black Bear** (uncataloged specimen, OSUCOV)

Medulla continuous, nodose type a, flattened "cells", occupies 1/3 to 1/2 of shaft. Cuticula imbricate, crenate, smooth to wavy large scales with mosaic arrangement. Midshaft dia. 102µm.

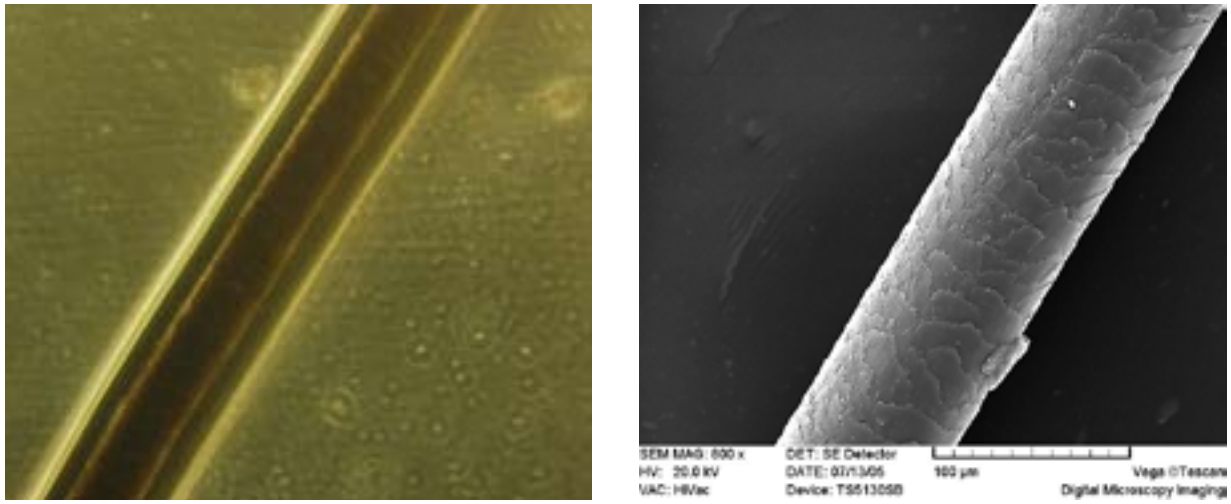

Figure 54. Medulla (left) and cuticula (right) of *Ursus americanus*.

***Ursus arctos* - Grizzly or Brown Bear** (TTU 109057)

Medulla continuous, nodose type a, flattened "cells", vacuolated, occupies 1/3 of shaft. Cuticula imbricate, crenate, with smooth large scales in broken rows. Midshaft dia. 100µm.

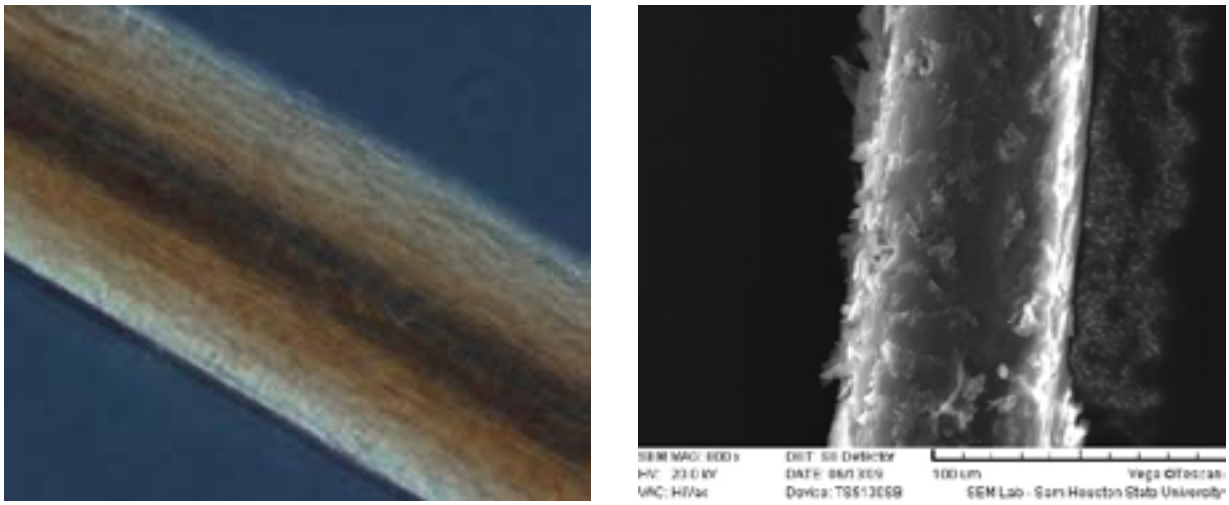

Figure 55. Medulla (left) and cuticula (right) of *Ursus arctos*.

Family Procyonidae

***Bassariscus astutus* - Ringtail** (SHM 295)

Medulla continuous, nodose type a, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, scales wavy and very close to each other. Midshaft dia. 73µm.

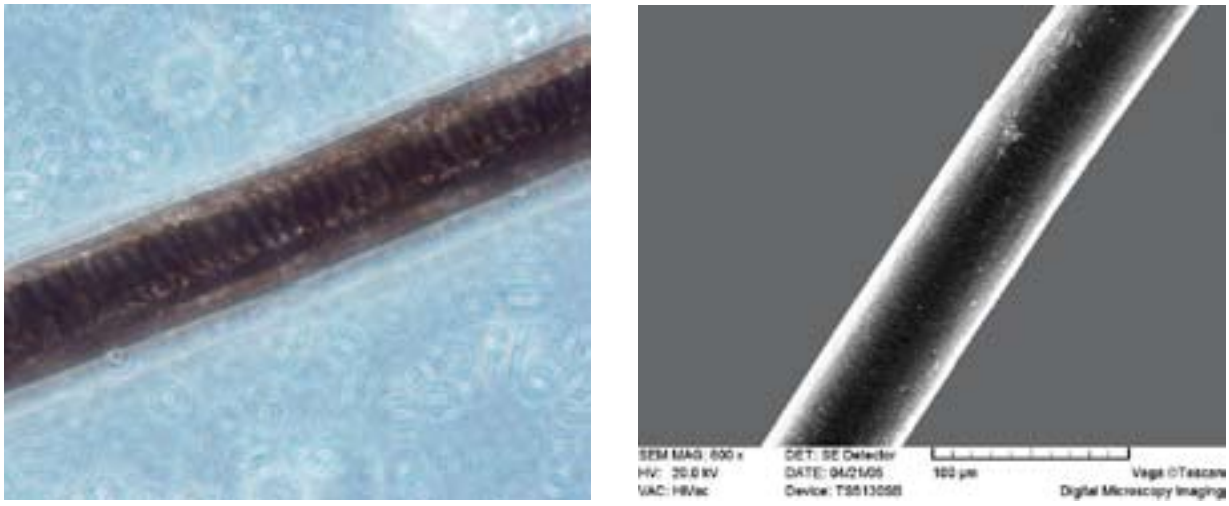

Figure 56. Medulla (left) and cuticula (right) of *Bassariscus astutus*.

***Procyon lotor* - Northern Raccoon** (SHM 522)

Medulla continuous, nodose type a, vacuolated, occupies 1/2 of shaft. Cuticula imbricate, flattened, with irregular rows. Midshaft dia. 113µm.

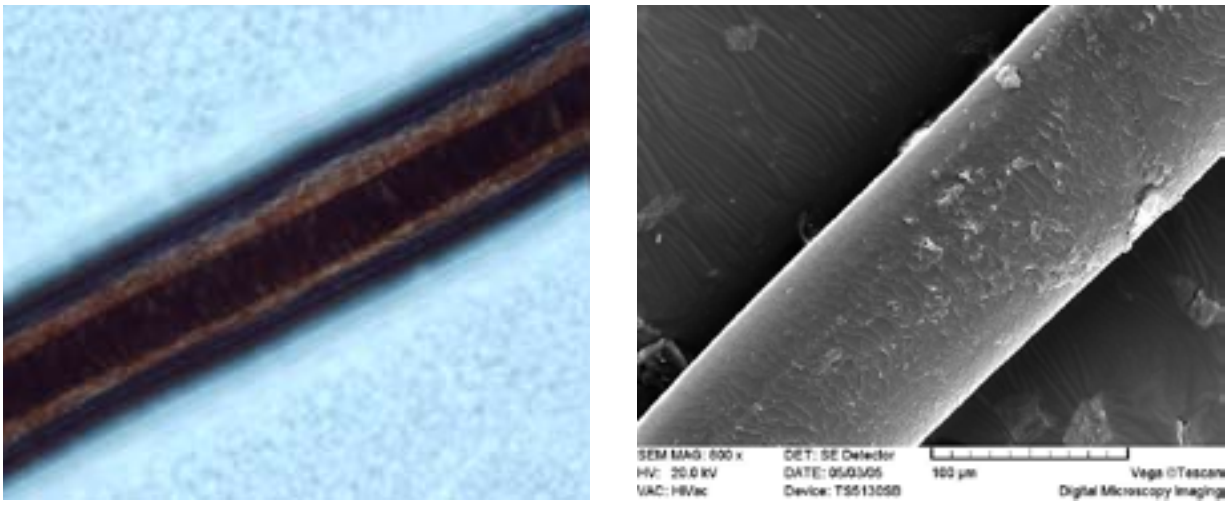

Figure 57. Medulla (left) and cuticula (right) of *Procyon lotor*.

***Nasua narica* - White-nosed Coati** (ASNHC 2674)

Medulla continuous, nodose type a, vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, crenate, with wavy rows. Midshaft dia. 60µm.

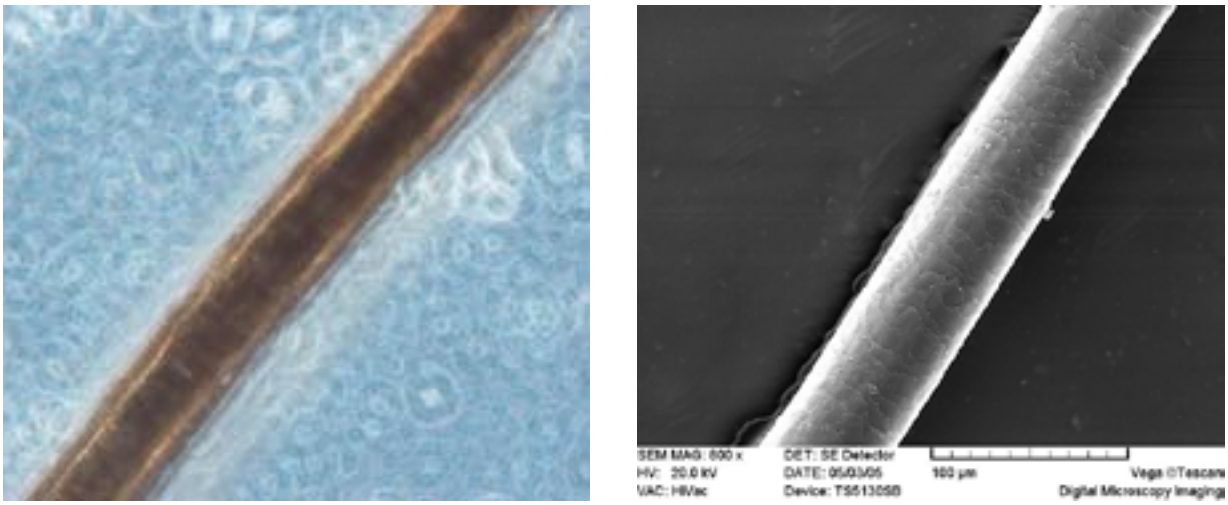

Figure 58. Medulla (left) and cuticula (right) of *Nasua narica*.

Family Mustelidae

***Mustela frenata* - Long-tailed Weasel** (SHM 193)

Medulla continuous, nodose type a, vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, with irregular rows. Midshaft dia. 78µm.

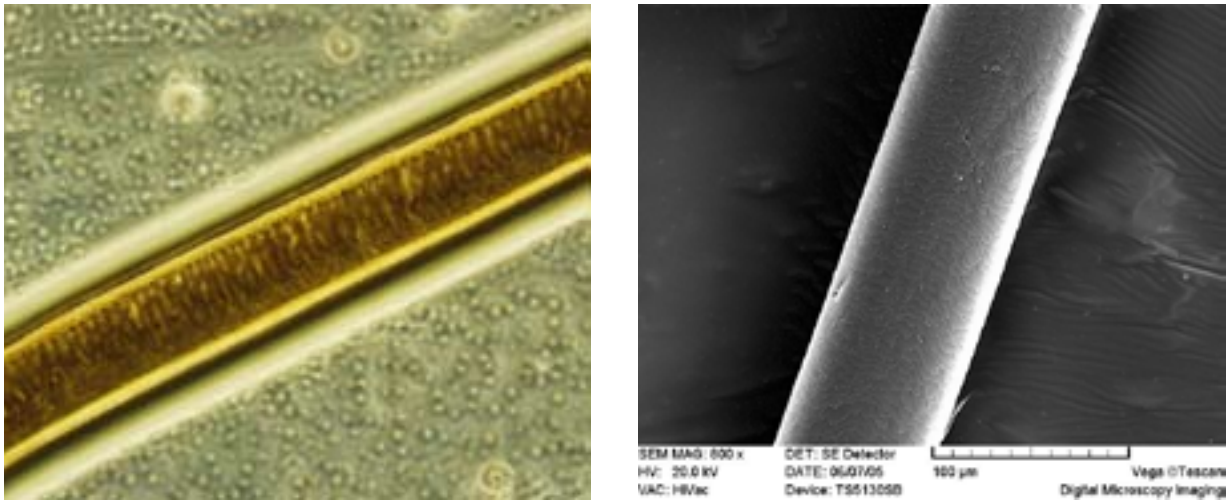

Figure 59. Medulla (left) and cuticula (right) of *Mustela frenata*.

***Mustela nigripes* - Black-footed Ferret** (OSUCOV 9266)

Medulla continuous, nodose type a, vacuolated, occupies more than 1/2 of shaft, some vacuoles very large and round. Cuticula imbricate, crenate, with large scales that are visible only occasionally. Midshaft dia. 85µm.

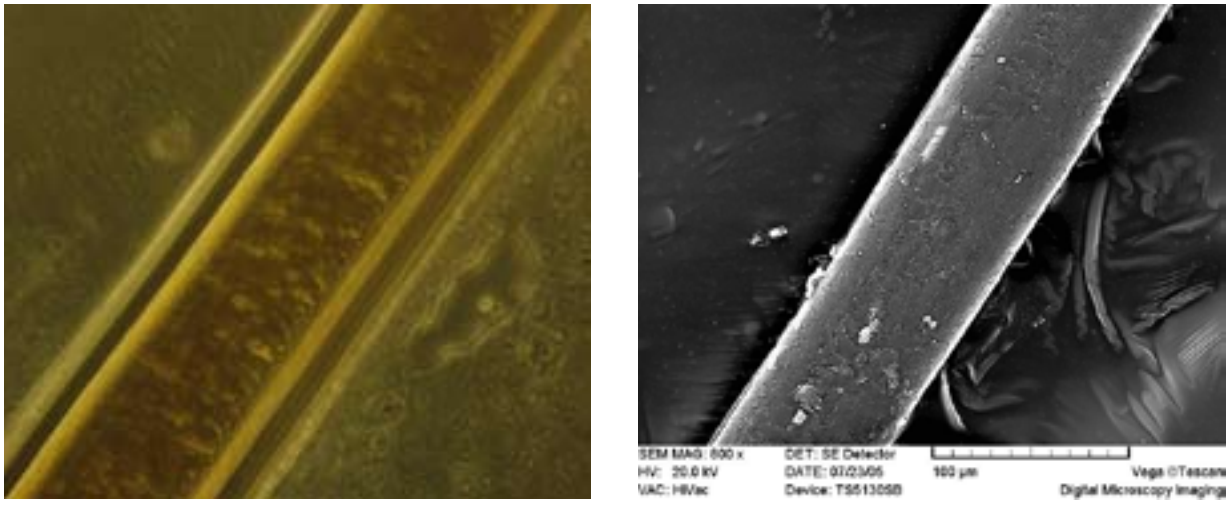

Figure 60. Medulla (left) and cuticula (right) of *Mustela nigripes*.

***Mustela vison* - American Mink** (SHM 925)

Medulla continuous, nodose type a, fully vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, extremely close and wavy rows. Midshaft dia. 140µm.

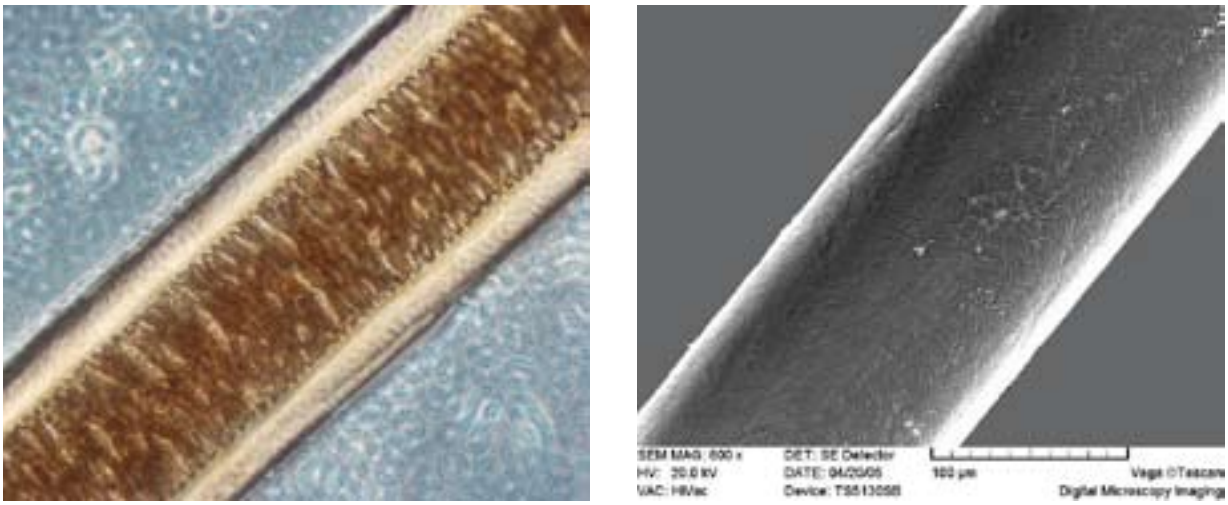

Figure 61. Medulla (left) and cuticula (right) of *Mustela vison*.

***Taxidea taxus* - American Badger** (SHM 677)

Medulla continuous, homogeneous type a, vacuolated, occupies 1/3 of shaft. Cuticula imbricate, undefined, rows wavy when present. Midshaft dia. 120µm.

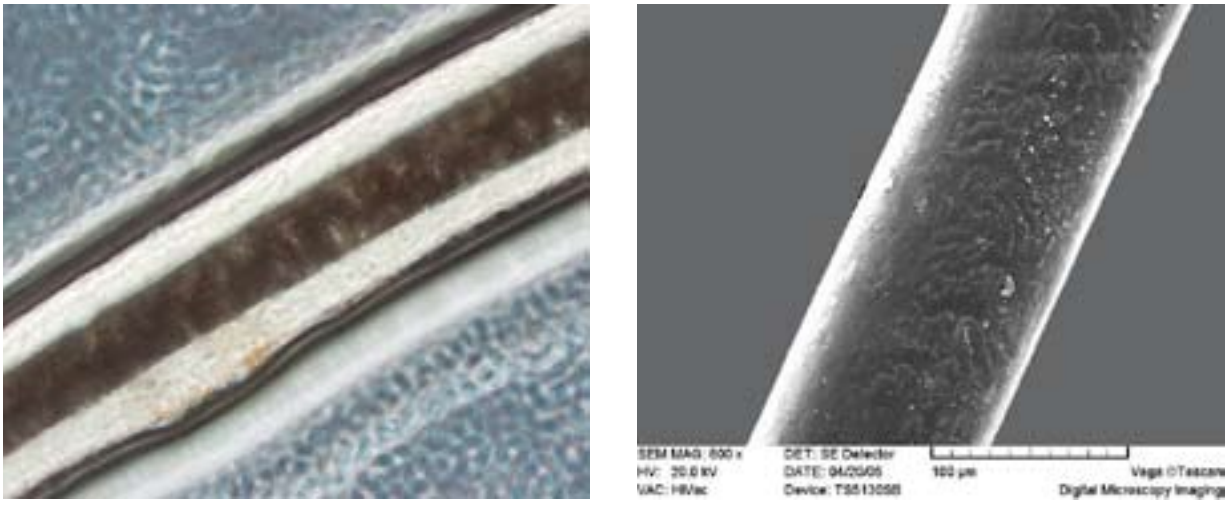

Figure 62. Medulla (left) and cuticula (right) of *Taxidea taxus*.

***Lontra canadensis* - Northern River Otter** (SHM 971)

Medulla continuous, nodose type a, vacuolated, flattened "cells", occupies 1/3 of shaft. Cuticula imbricate, flattened, wavy scales and rows, 1-2 scales per row. Midshaft dia. 162µm.

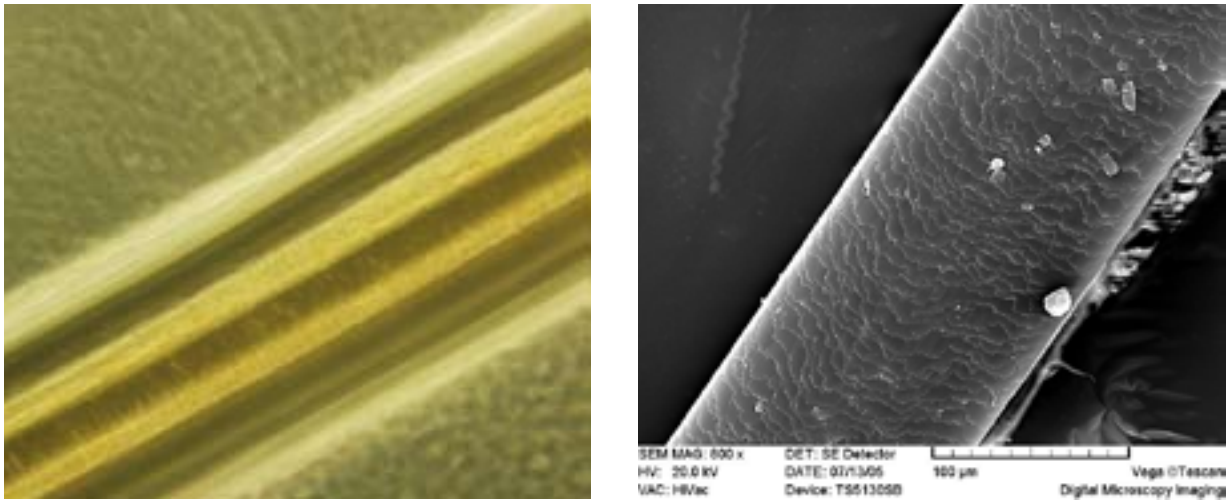

Figure 63. Medulla (left) and cuticula (right) of *Lontra canadensis*.

Family Mephitidae

***Spilogale gracilis* - Western Spotted Skunk** (ASNHC 10967)

Medulla discontinuous, compound ovate, "cells" form 2 columns, most rows fused, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, wavy and parallel rows. Midshaft dia. 118µm.

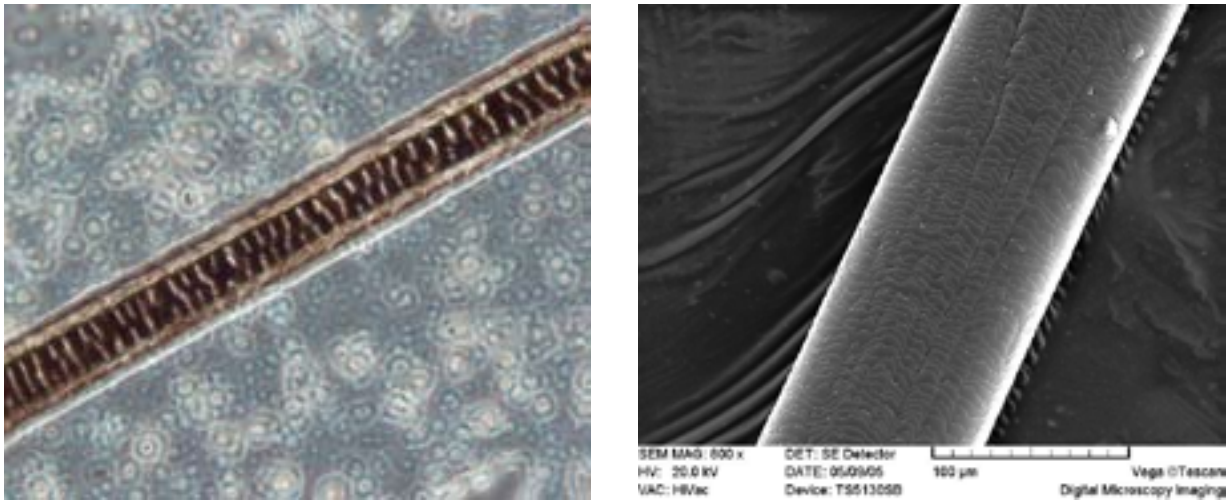

Figure 64. Medulla (left) and cuticula (right) of *Spilogale gracilis*.

***Spilogale putorius* - Eastern Spotted Skunk** (SHM 208)

Medulla continuous, nodose type a, fully vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, wavy scales and rows. Midshaft dia. 90µm.

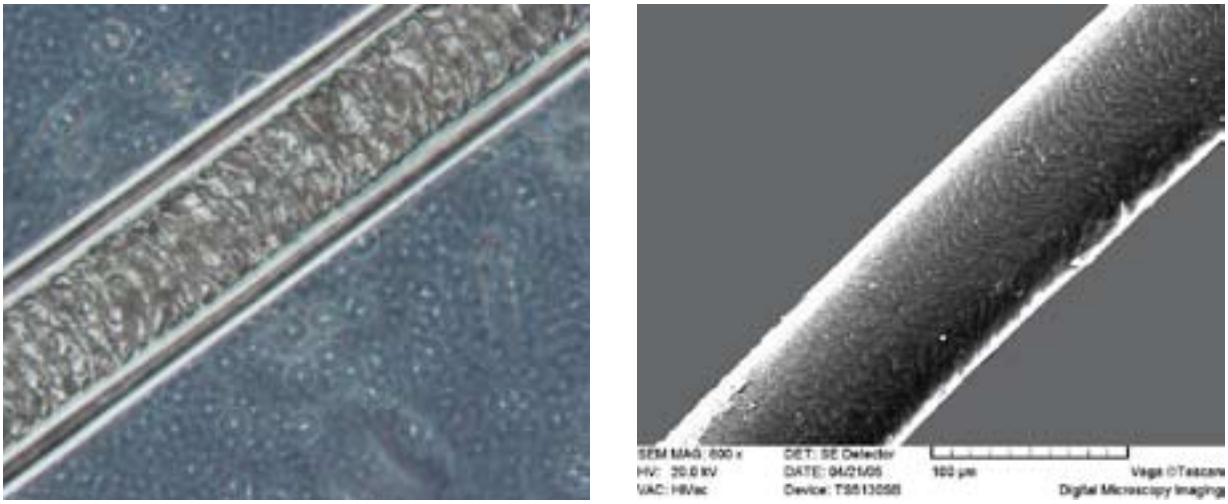

Figure 65. Medulla (left) and cuticula (right) of *Spilogale putorius*.

***Mephitis macroura* - Hooded Skunk** (TCWC-catalog number not recorded)

Medulla continuous, homogeneous type b, vacuolated, occupies entire shaft. Cuticula imbricate, flattened, wavy scales and disturbed rows. Midshaft dia. 140µm.

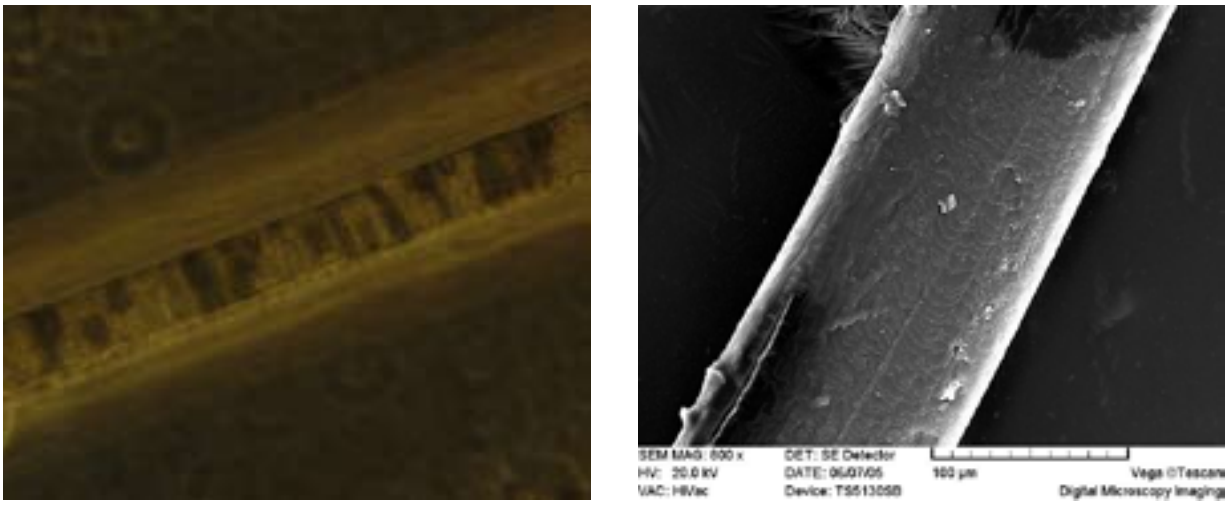

Figure 66. Medulla (left) and cuticula (right) of *Mephitis macroura*.

***Mephitis mephitis* - Striped Skunk** (SHM 69)

Medulla continuous, homogeneous type b, vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, wavy and irregular rows. Midshaft dia. 125µm.

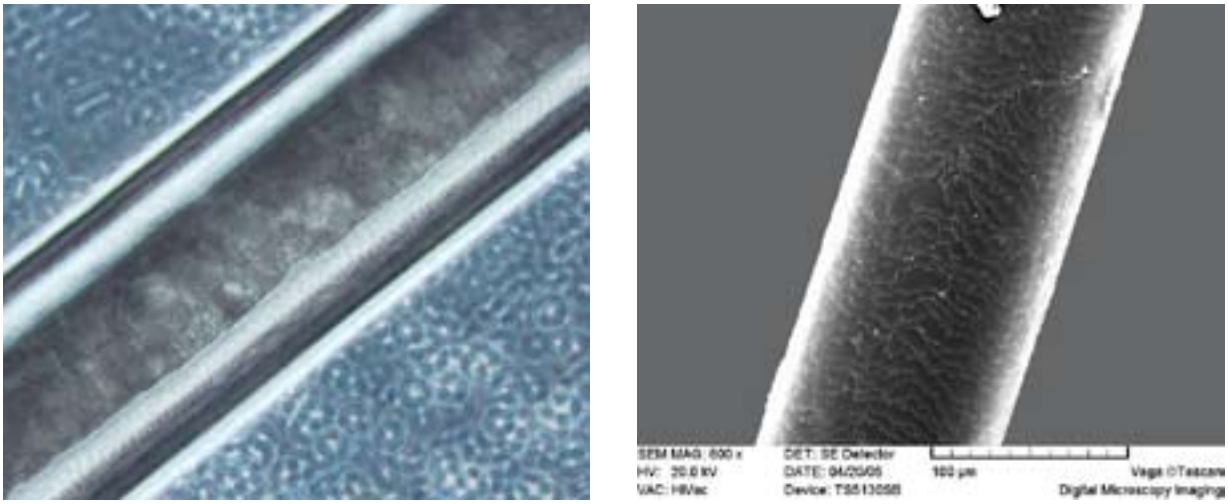

Figure 67. Medulla (left) and cuticula (right) of *Mephitis mephitis*.

***Conepatus leuconotus* - Hog-nosed Skunk** (SHM 257)

Medulla continuous, homogeneous type a, vacuolated, occupies 1/3 of shaft. Cuticula imbricate, flattened, wavy scales and disturbed rows. Midshaft dia. 137µm.

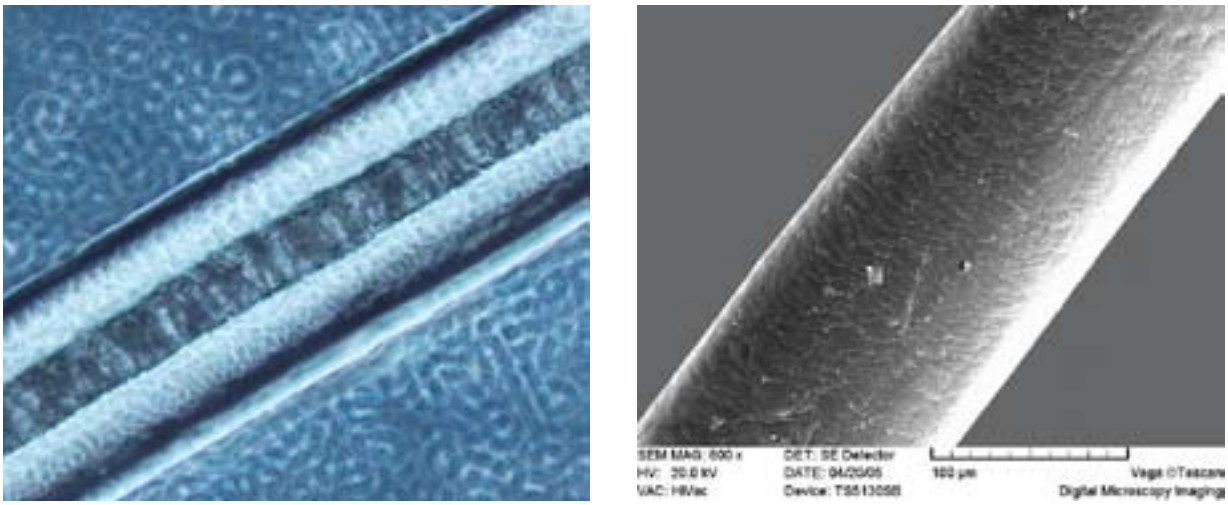

Figure 68. Medulla (left) and cuticula (right) of *Conepatus leuconotus*.

Family Felidae

***Puma concolor* - Mountain Lion** (SHM 287)

Medulla continuous, nodose type a, vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, wavy scales, no rows. Midshaft dia. 100µm.

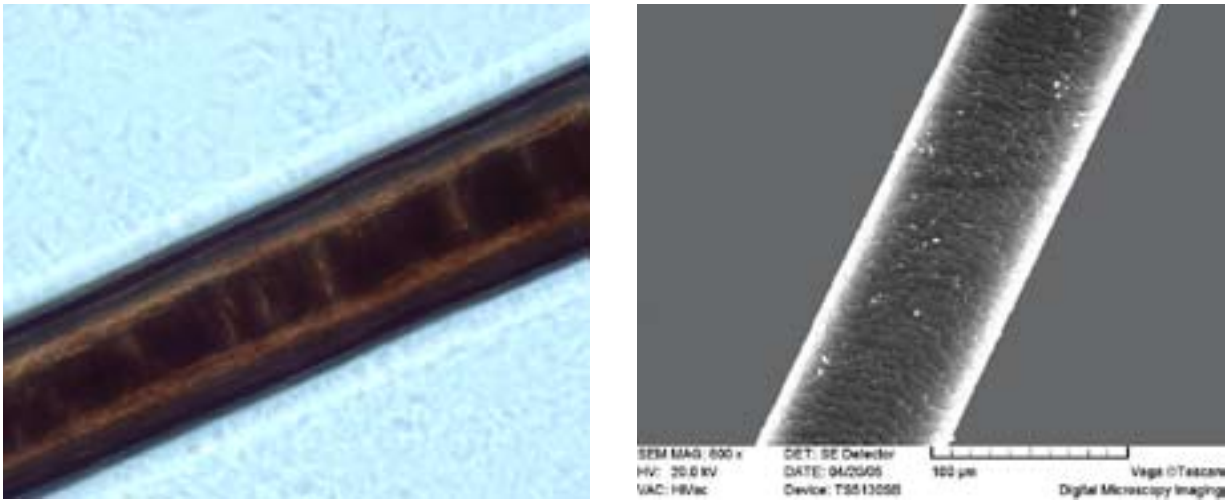

Figure 69. Medulla (left) and cuticula (right) of *Puma concolor*.

***Leopardus pardalis* - Ocelot** (TCWC 12945)

Medulla continuous, nodose type a, vacuolated, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, wavy scales, some rows disturbed. Midshaft dia. 64µm.

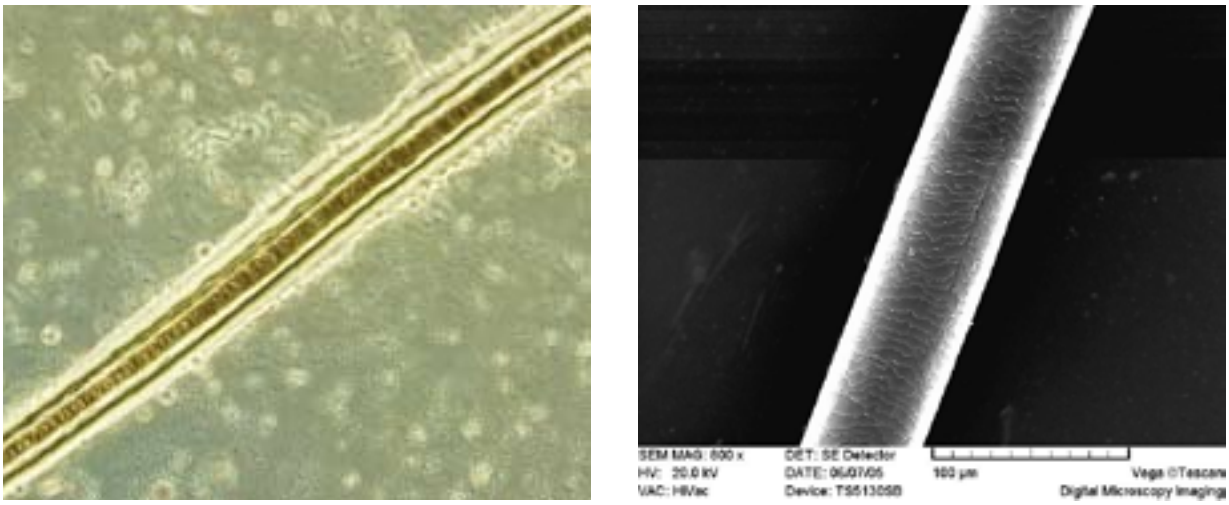

Figure 70. Medulla (left) and cuticula (right) of *Leopardus pardalis*.

***Leopardus wiedii* – Margay** (Houston Zoological Park)

Medulla continuous, nodose type a, with large square "cells", occupies 1/3 of shaft. Cuticula imbricate, flattened, 1-2 wavy scales per row. Midshaft dia. 55µm.

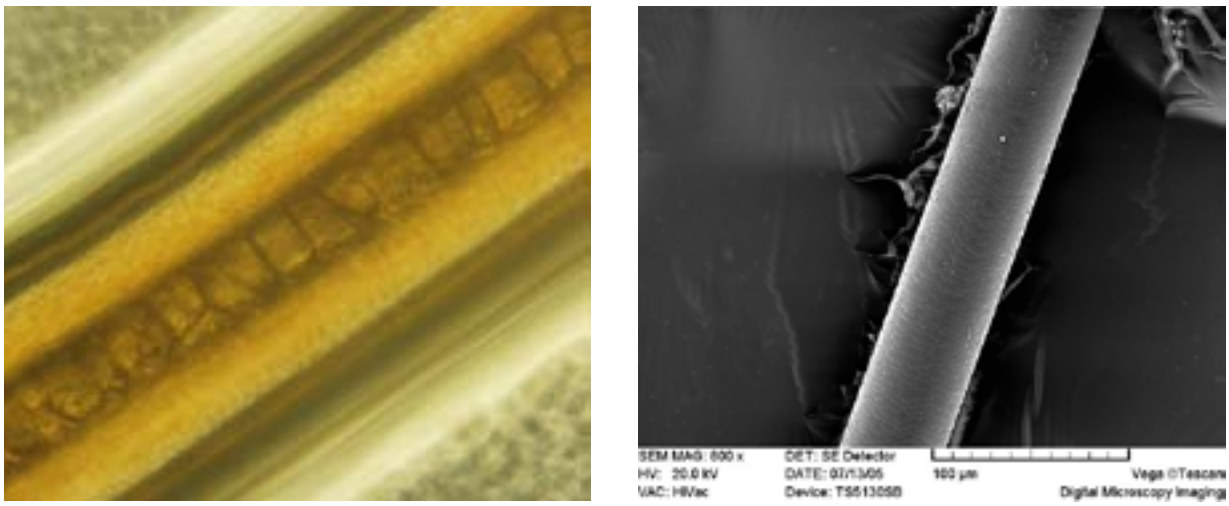

Figure 71. Medulla (left) and cuticula (right) of *Leopardus wiedii*.

***Herpailurus yaguarondi* - Jaguarundi** (ASNHC 3891)

Medulla continuous, nodose type a, vacuolated, occupies entire shaft. Cuticula imbricate, flattened, smooth and small scales. Midshaft dia. 134µm.

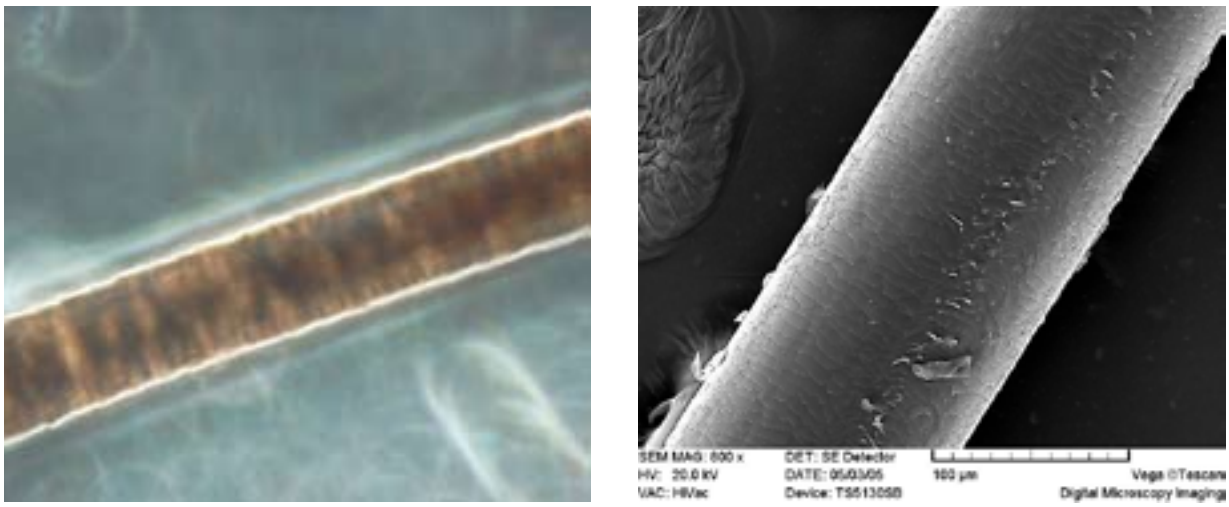

Figure 72. Medulla (left) and cuticula (right) of *Herpailurus yaguarondi*.

***Lynx rufus* - Bobcat** (SHM 246)

Medulla continuous, nodose type a, vacuolated, occupies entire shaft. Cuticula imbricate, flattened, with wavy scales and rows. Midshaft dia. 62µm.

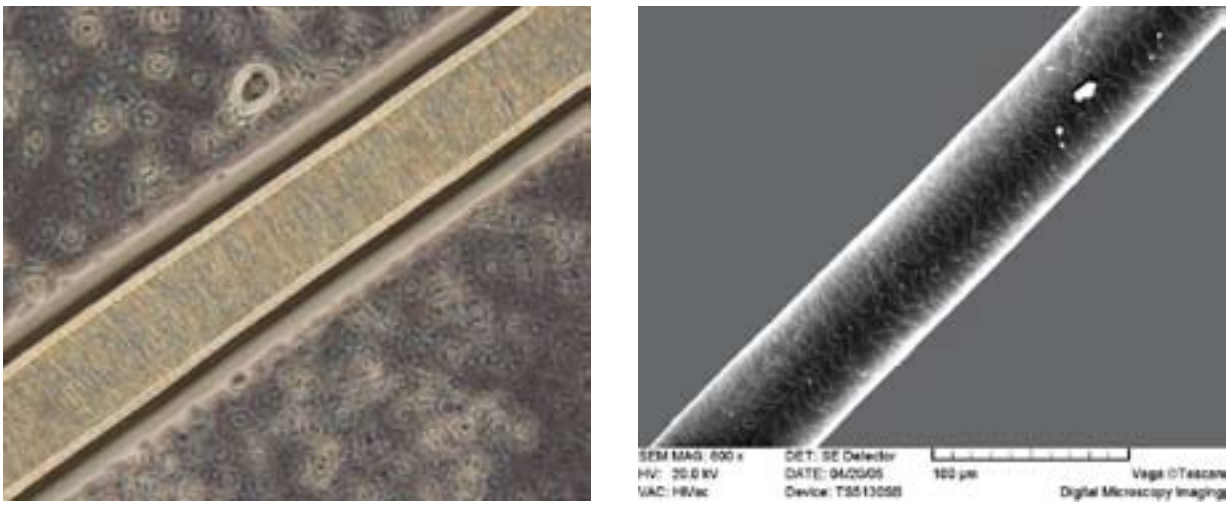

Figure 73. Medulla (left) and cuticula (right) of *Lynx rufus*.

***Panthera onca* - Jaguar** (TTU 59091)

Medulla continuous, homogeneous mixed type a and b or not penetrated, occupies from 1/3 to entire shaft. Cuticula imbricate, crenate, with wavy and irregular scales and rows, often disturbed. Midshaft dia. 95µm.

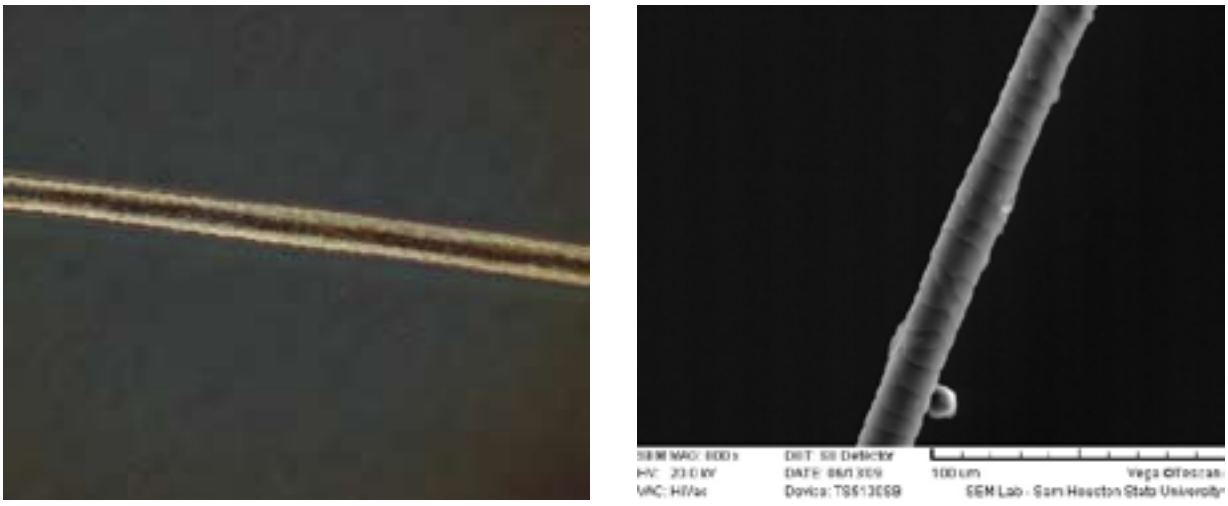

Figure 74. Medulla (left) and cuticula (right) of *Panthera onca*.

ORDER PERISSODACTYLA – ODD-TOED UNGULATES

1. Medulla discontinuous, fragmental (Fig. 4a).....*Equus caballus* (Fig. 75)
   Medulla continuous.....*Equus asinus* (Fig. 76)

Family Equuidae

***Equus caballus* - *Horse** (TTU 40986)

Medulla discontinuous, fragmental type a, occupies 1/3 of shaft. Cuticula imbricate, flattened, with irregular and wavy rows. Midshaft dia. 116µm.

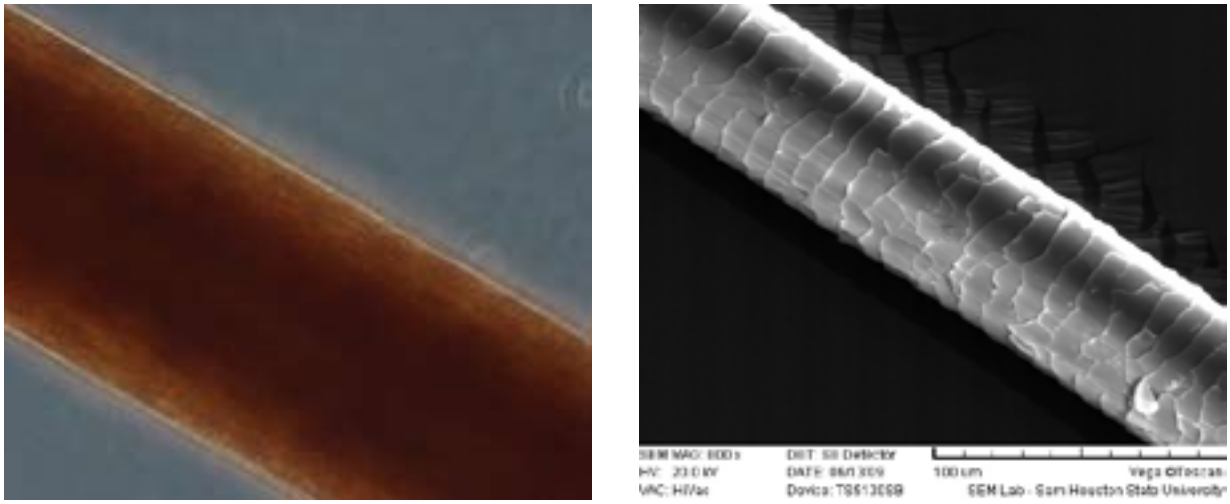

Figure 75. Medulla (left) and cuticula (right) of *Equus caballus*.

***Equus asinus* - *Donkey** (R. Smith)

Medulla continuous, homogeneous type a, occupies more than 1/2 of shaft. Cuticula imbricate, flattened, with irregular and wavy rows. Midshaft dia. 93µm.

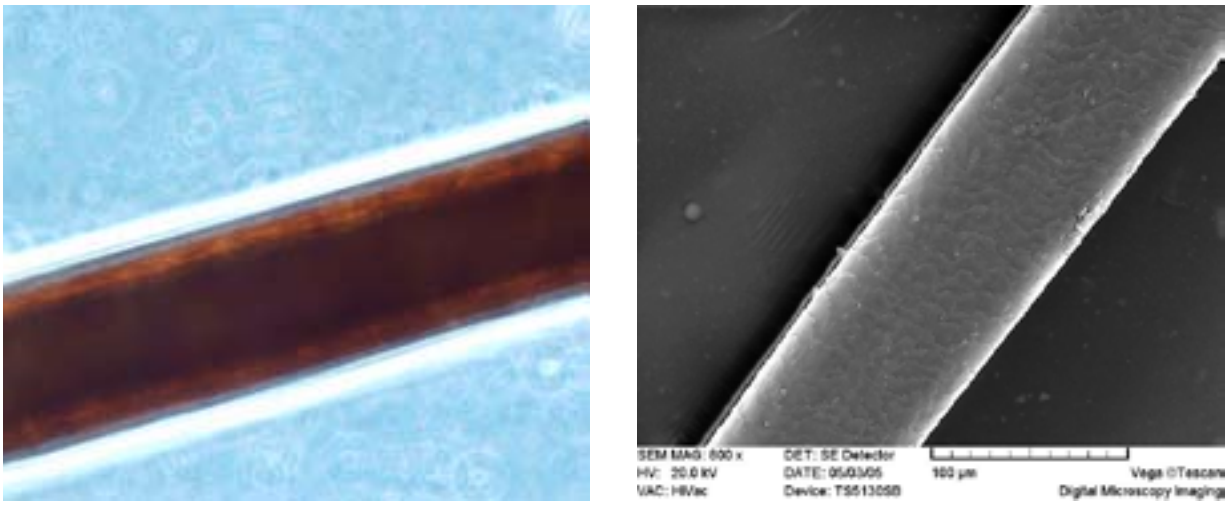

Figure 76. Medulla (left) and cuticula (right) of *Equus asinus*.

ORDER ARTIODACTYLA – EVEN-TOED UNGULATES

1. Medulla discontinuous, fragmental (Fig. 4).....*Bos bison* (Fig. 85)
   Medulla continuous (Figs. 5-6).....2

2. Medulla homogeneous (Fig. 6).....3
   Medulla nodose (Fig. 5).....5

3. Medulla homogeneous type a (Fig. 6).....*Lama glama* (Fig. 79)
   Medulla other than homogeneous type a (Fig. 6), not penetrated, cuticula flattened (Fig. 7e).....4

4. Rows close and wavy.....*Pecari tajacu* (Fig. 78)
   Scales absent in many areas, in places where scales are present rows are close and wavy.....*Sus scrofa* (Fig. 77)

5. Medulla is disturbed.....6
   Medulla is not disturbed.....7

6. Cortical intrusions present, shaft d>100µm.....*Capra hircus* (Fig. 90)
   Medulla occupies 1/3 of the shaft, shaft d<100µm.....*Ovis aries* (Fig. 86)

7. Cuticula flattened (Fig. 7e).....*Antilope cervicapra* (Fig. 89)
   Cuticula crenate (Fig. 7d).....8

8. Cuticula has "fish scale" pattern, scales oval and uniform in shape,
   scales lay close to the surface of the hair.....*Antilocapra americana* (Fig. 84)
   Cuticula does not have "fish scale" pattern.....9

9. Medulla occupies entire shaft.....*Ovis canadensis* (Fig. 87)
   Medulla occupies less than entire shaft.....10

10. Medulla occupies 1/2 of shaft.....11
    Medulla occupies more than 1/2 of shaft.....12

11. Medulla not rounded, scales smooth, shaft d<200µm.....*Cervus elaphus* (Fig. 81)
    Medulla rounded, scales smooth, shaft d>200µm.....*Odocoileus hemionus* (Fig. 82)

12. Cuticula has "elephant skin" appearance, shaft d<100µm.....*Ammotragus lervia* (Fig. 88)
Cuticula does not have "elephant skin" appearance.....13

13. Scales not smooth, rows disturbed.....*Cervus axis* (Fig. 80)
Scales smooth.....*Odocoileus virginiana* (Fig. 83)

Family Suidae

***Sus scrofa* - *Feral Pig** (SHM 972)

Medulla continuous, homogeneous, not penetrated, and occupies entire shaft. Cuticula imbricate, flattened, scales often absent in large areas but when present form extremely close and wavy rows. Midshaft dia. 270µm.

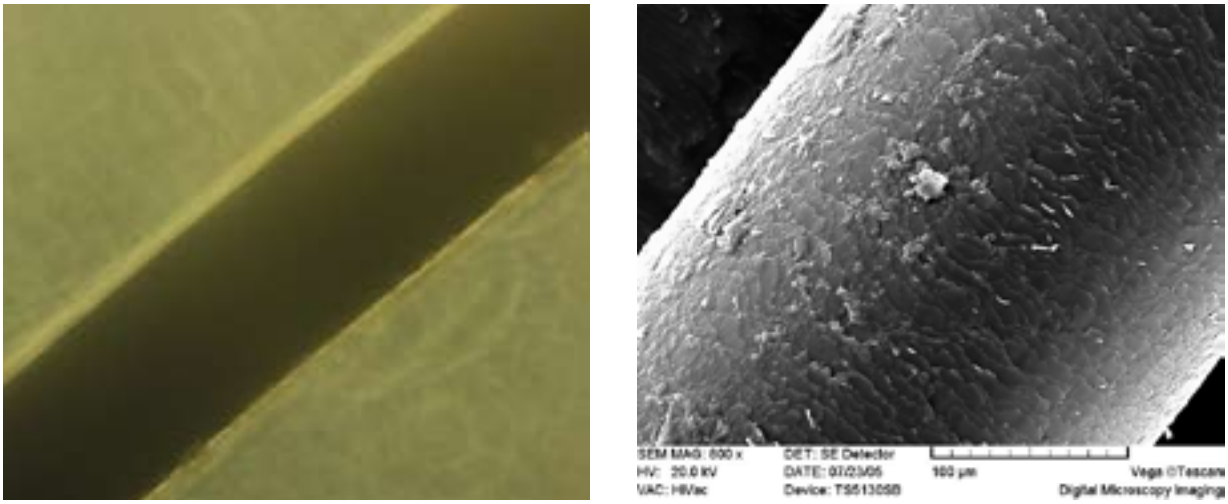

Figure 77. Medulla (left) and cuticula (right) of *Sus scrofa*.

Family Tayassuidae

***Pecari tajacu* - Collared Peccary** (SHM 973)

Medulla continuous, homogeneous, completely unpenetrated and occupies entire shaft. Cuticula imbricate, flattened, with extremely close and wavy rows. Midshaft dia. 224µm.

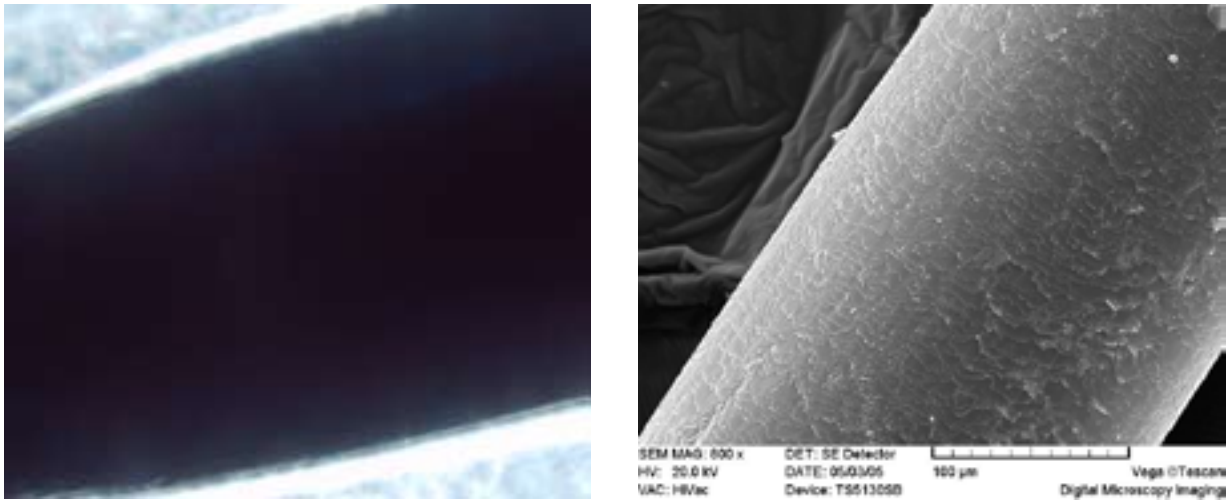

Figure 78. Medulla (left) and cuticula (right) of *Pecari tajacu*.

Family Camelidae

***Lama glama* - *Lama** (R. Smith)

Medulla continuous, homogeneous type a, occupies 1/3 of shaft. Cuticula imbricate, crenate, scales not smooth, with parallel and equal rows. Midshaft dia. 56µm.

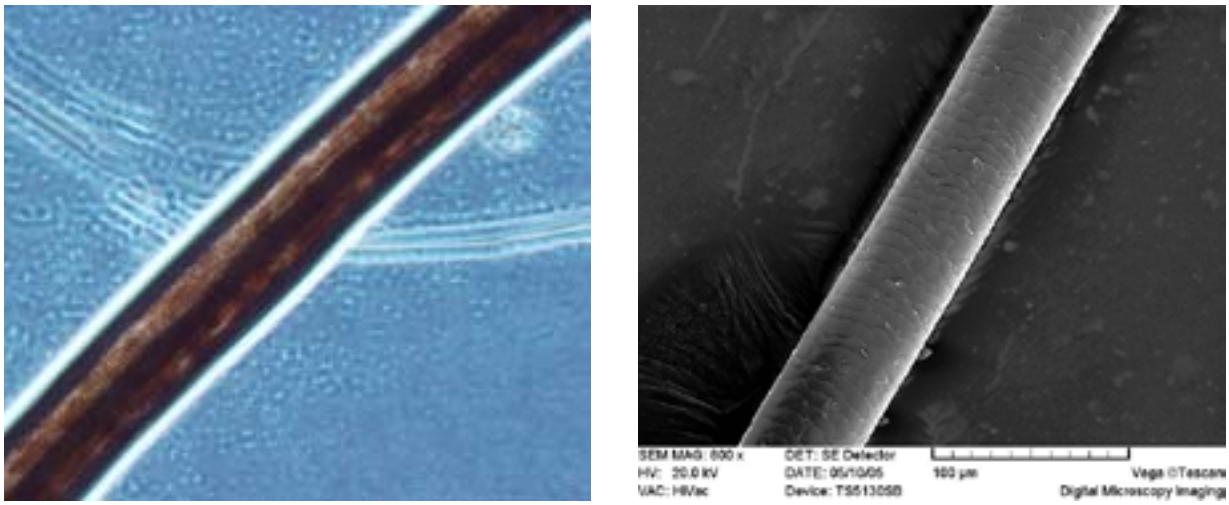

Figure 79. Medulla (left) and cuticula (right) of *Lama glama*.

Family Cervidae

***Cervus axis* - *Axis Deer** (SHM 974)

Medulla continuous, nodose type b, unordered and undisturbed, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, scales not smooth, rows broken. Midshaft dia. 115µm.

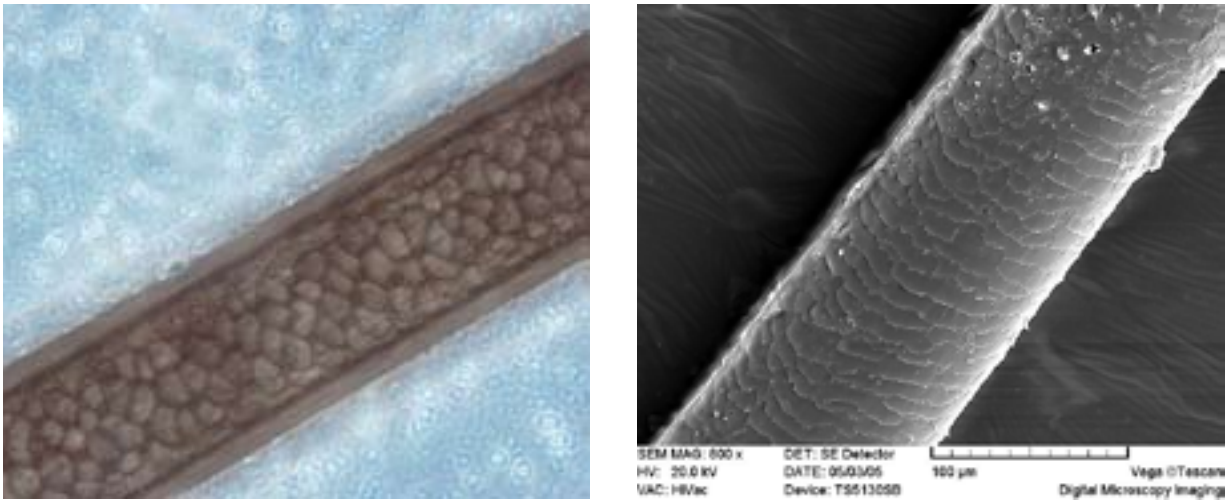

Figure 80. Medulla (left) and cuticula (right) of *Cervus axis*.

***Cervus elaphus* – Elk** (SHM 975)

Medulla continuous, nodose type b, unordered and undisturbed, not rounded, and occupies 1/2 of shaft. Cuticula imbricate, crenate, scales not smooth, rows uneven. Midshaft dia. 175µm.

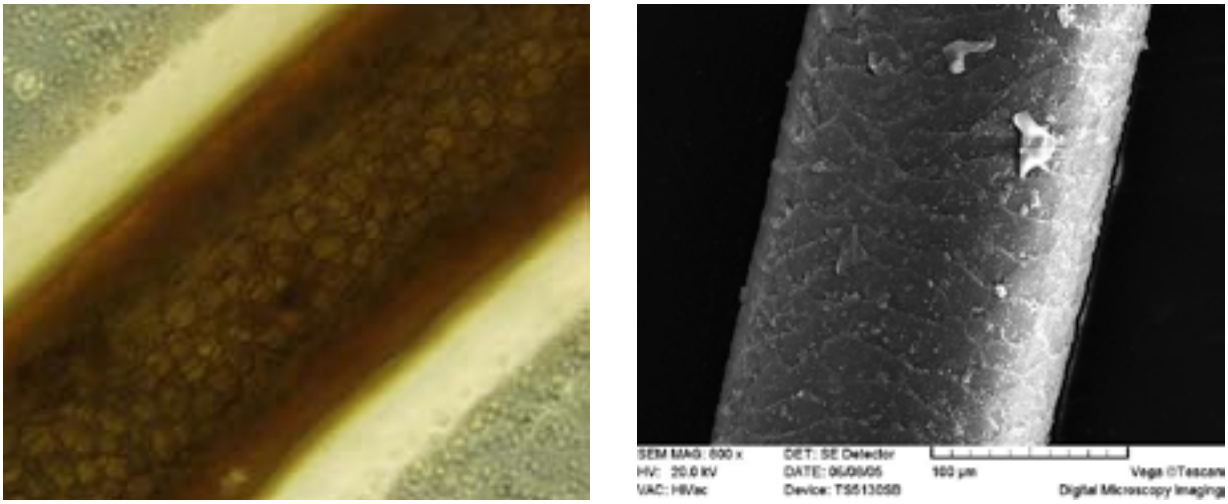

Figure 81. Medulla (left) and cuticula (right) of *Cervus elaphus*.

***Odocoileus hemionus* - Mule Deer** (SHM 362)

Medulla continuous, nodose type b, unordered and undisturbed, rounded, and occupies 1/2 of shaft. Cuticula imbricate, crenate, smooth scales, mosaic, "elephant skin" pattern. Midshaft dia. 245µm.

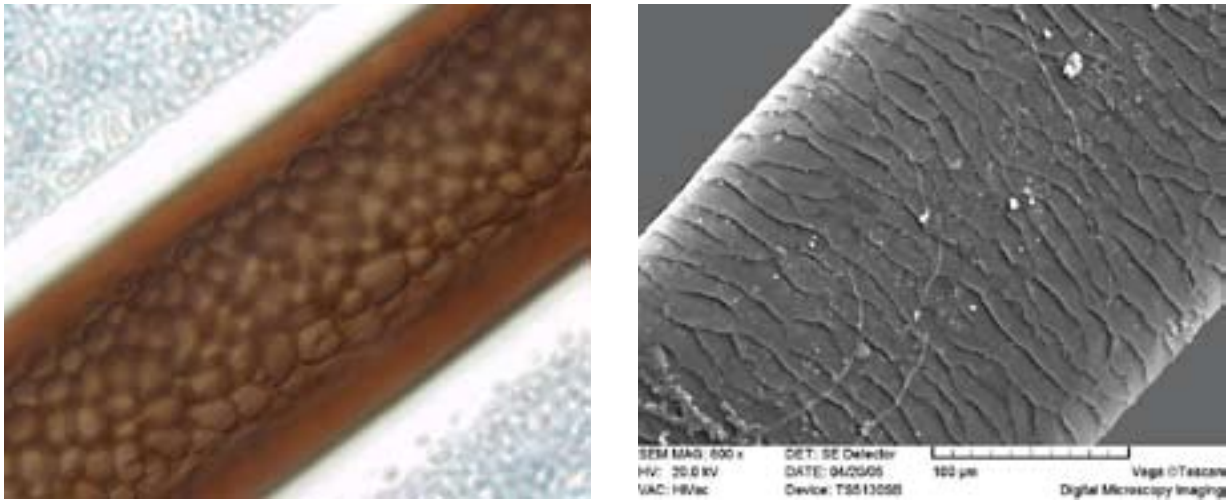

Figure 82. Medulla (left) and cuticula (right) of *Odocoileus hemionus*.

***Odocoileus virginianus* - White-tailed Deer** (ASNHC 7040)

Medulla continuous, nodose type b, unordered, undisturbed, central part is best differentiated, occupies more than 1/2 of shaft. Cuticula imbricate, crenate, smooth scales. Midshaft dia. 125µm.

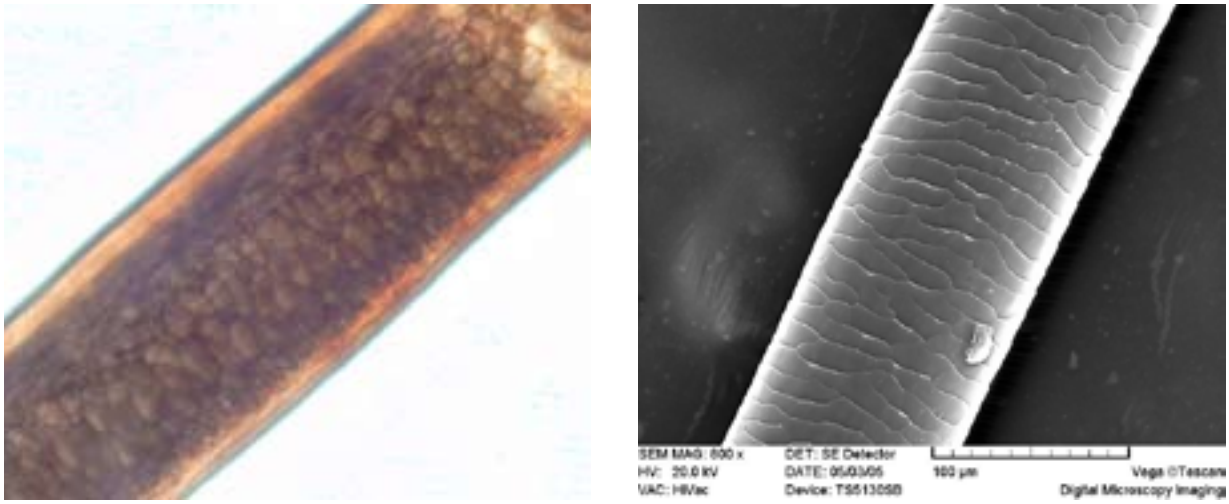

Figure 83. Medulla (left) and cuticula (right) of *Odocoileus virginianus*.

Family Antilocapridae

***Antilocapra americana* - Pronghorn** (ASNHC 7924)

Medulla continuous, nodose type b, unordered, undisturbed. Cuticula imbricate, crenate, fish scale-like. Midshaft dia. 425µm.

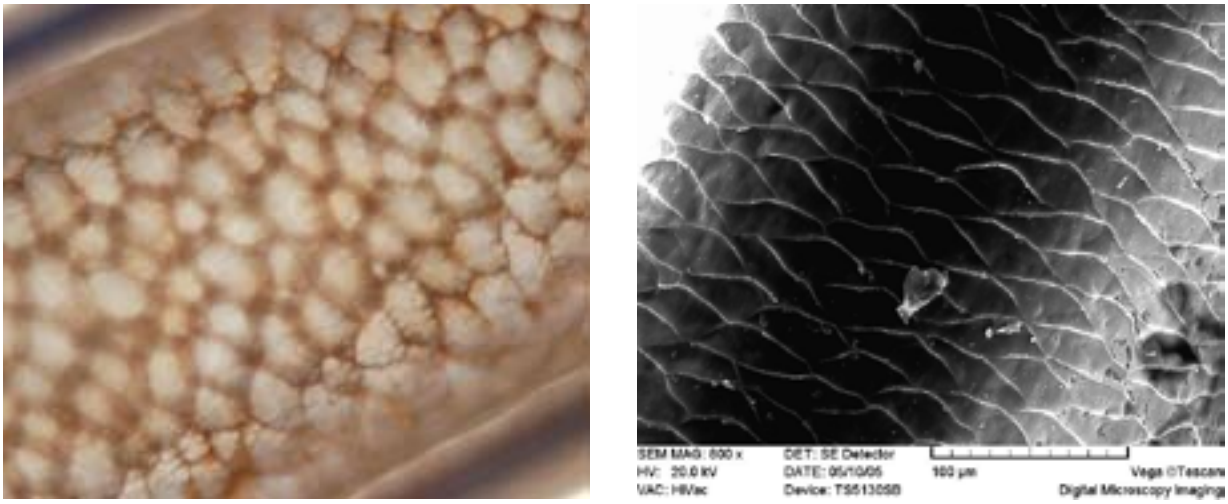

Figure 84. Medulla (left) and cuticula (right) of *Antilocapra americana*.

Family Bovidae

***Bos bison* - American Bison** (TTU 40503)

Medulla discontinuous, fragmental type a, large chunks of medulla occasionally present occupying more than 1/3 of shaft. Cuticula imbricate, crenate, wavy scales, irregular and disrupted rows. Midshaft dia. 97µm.

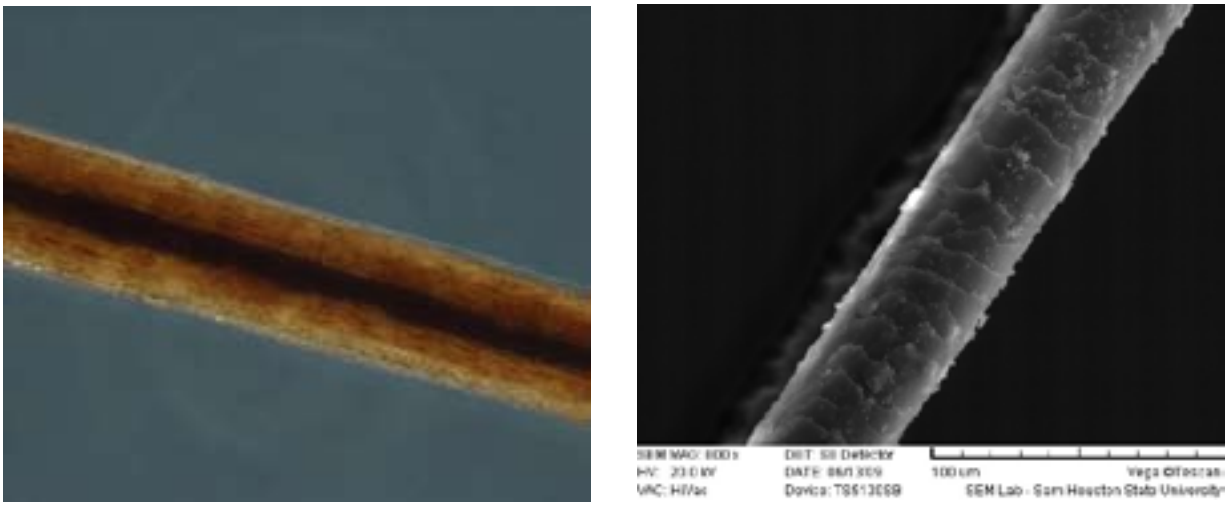

Figure 85. Medulla (left) and cuticula (right) of *Bos bison*.

***Ovis aries* - *Domestic Sheep** (R. Smith)

Medulla continuous, nodose type b, unordered, disturbed, and occupies 1/3 of shaft. Cuticula imbricate, crenate, scales tall and not smooth, rows parallel and equal. Midshaft dia. 30µm.

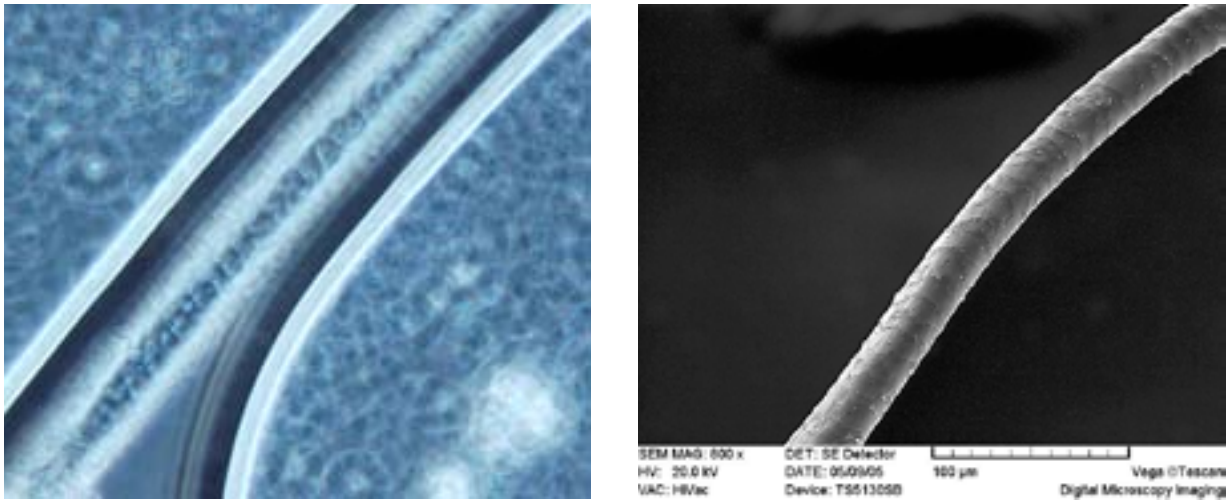

Figure 86. Medulla (left) and cuticula (right) of *Ovis aries*.

***Ovis canadensis* - Bighorn Sheep** (TTU 40394)

Medulla continuous, nodose type b, unordered and undisturbed, rounded, formed by "cells" uneven in size, and occupies entire shaft. Cuticula imbricate, crenate, wavy scales, irregular and disrupted rows. Midshaft dia. 130µm.

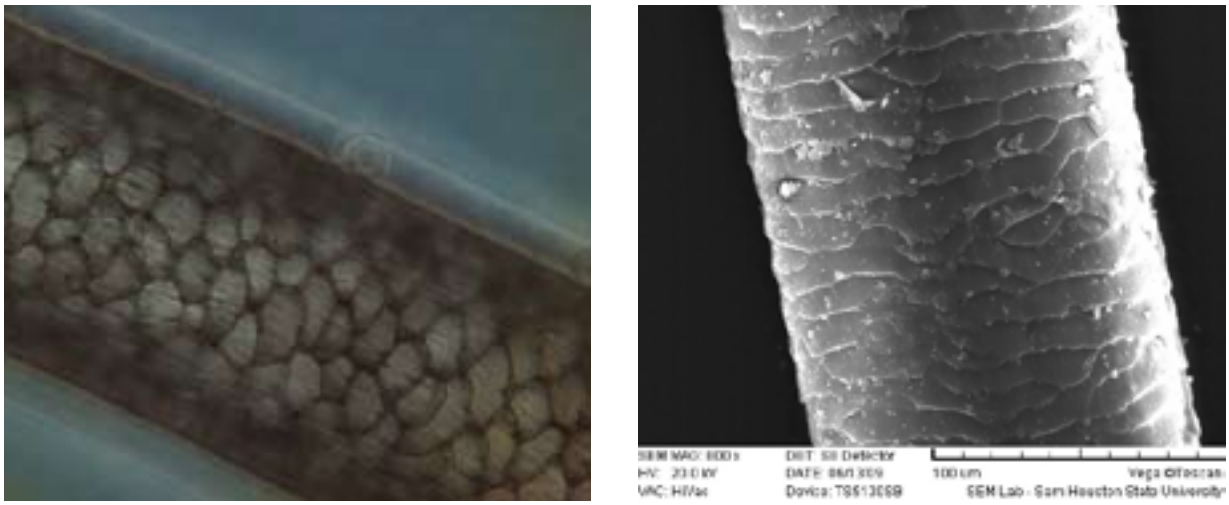

Figure 87. Medulla (left) and cuticula (right) of *Ovis canadensis*.

***Ammotragus lervia* - *Barbary Sheep or Aoudad** (OSUCOV 12107)

Medulla continuous, nodose type b, unordered and undisturbed, "cells" are somewhat square, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, with "elephant-skin" pattern, smooth scales, some rows disturbed. Midshaft dia. 80µm.

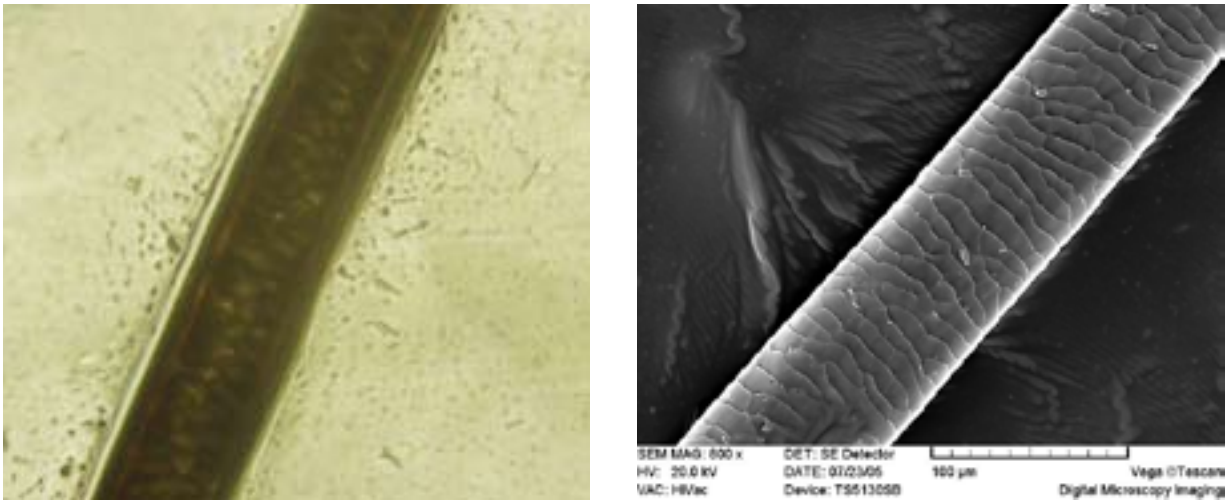

Figure 88. Medulla (left) and cuticula (right) of *Ammotragus lervia*.

***Antilope cervicapra* - *Blackbuck** (TTU 109508)

Medulla continuous, nodose type b, unordered and undisturbed, "cells" very flattened, and occupies more than 1/2 of shaft. Cuticula imbricate, flattened, with wavy scales and rows, multiple scales/row. Midshaft dia. 135µm.

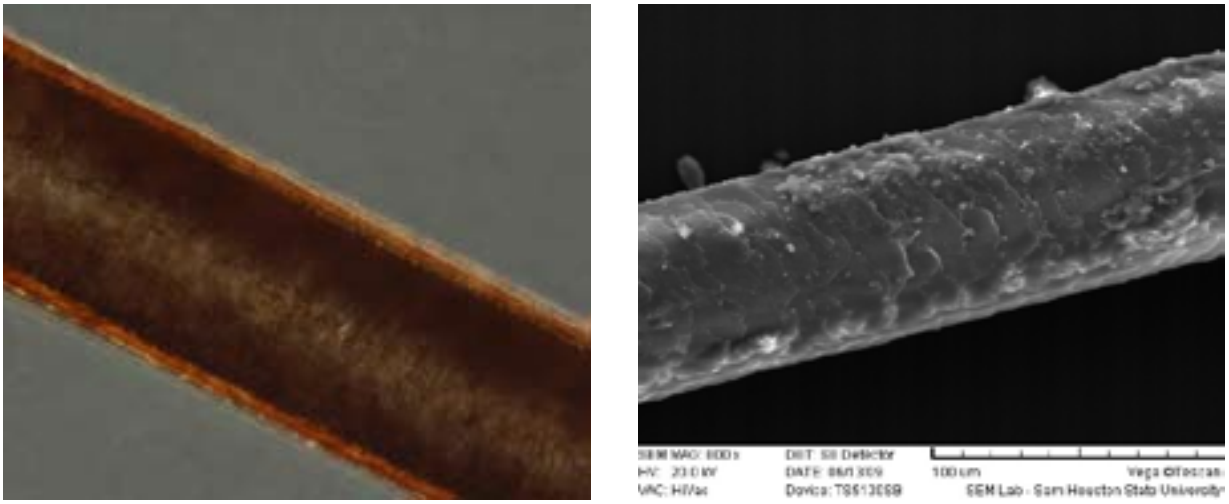

Figure 89. Medulla (left) and cuticula (right) of *Antilope cervicapra*.

***Capra hircus* - *Goat** (R. Smith)

Medulla continuous, nodose type b, unordered, disturbed, with cortical intrusions. Cuticula imbricate, flattened, with irregular and wavy rows. Midshaft dia. 203µm.

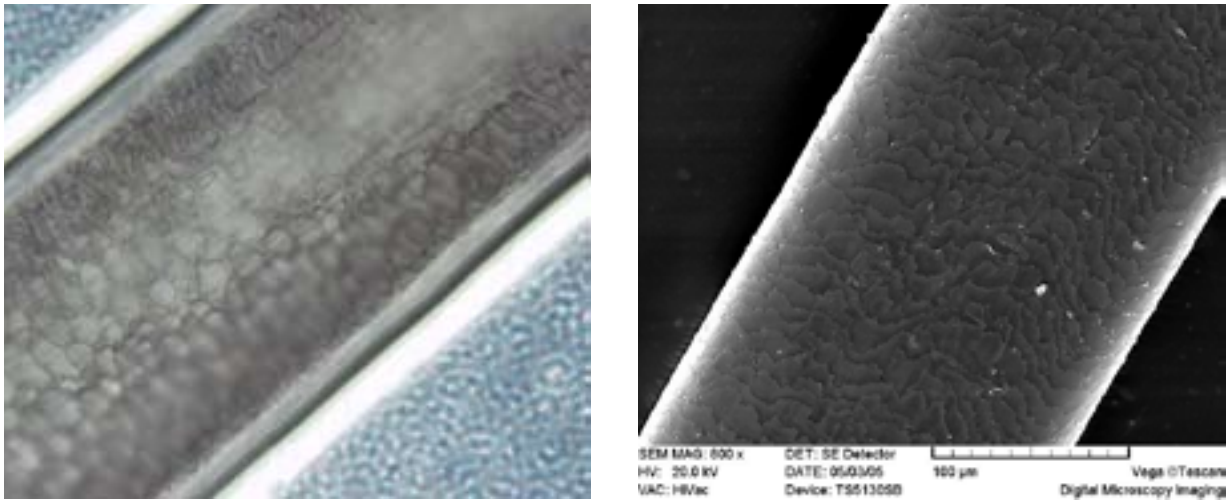

Figure 90. Medulla (left) and cuticula (right) of *Capra hircus*.

ORDER RODENTIA

1. Medulla discontinuous (Fig. 2-4).....2
   Medulla continuous (Fig. 5-6).....57

2. Medulla simple (Fig. 2).....3
   Medulla other than simple.....6

3. Medulla simple type c (Fig. 2c).....*Ochrotomys nuttalli* (Fig. 136)
   Medulla simple type a (Fig. 2a).....4

4. Medulla "cells" square.....*Onychomys leucogaster* (Fig. 139)
   Medulla "cells" not square.....5

5. Medulla "cells" oval.....*Peromyscus attwateri* (Fig. 128)
   Medulla "cells" rectangular.....*Peromyscus maniculatus* (Fig. 133)

6. Medulla fragmental (Fig. 4).....7
   Medulla compound (Fig. 3).....14

7. Medulla fragmental type a (Fig. 4a).....*Castor canadensis* (Fig. 121)
   Medulla fragmental but not type a (Fig. 4).....8

8. Medulla fragmental type b (Fig. 4b).....9
   Medulla fragmental type c (Fig. 4c).....11

9. Shaft d>300µm.....*Liomys irroratus* (Fig. 120)
   Shaft d<300µm.....10

10. Shaft d<100µm.....*Ammospermophilus interpres* (Fig. 92)
    Shaft 100<d<300µm.....*Erethizon dorsatum* (Fig. 153)

11. Scales flattened (Fig. 7e).....*Spermophilus variegatus* (Fig. 96)
    Scales other than flattened.....12

12. Scales acuminate (Fig. 7b).....13
    Scales elongate (Fig. 7c).....*Sigmodon ochrognathus* (Fig. 142)

13. Shaft d>200µm.....*Rattus norvegicus* (Fig. 150)
Shaft d<200µm.....*Rattus rattus* (Fig. 151)

14. Medulla ovate (Fig. 3).....15
Medulla other than ovate (Fig. 3).....24

15. Scales elongate (Fig. 7c).....16
Scales crenate (Fig. 7d).....17

16. Medullar "cells" form 3 columns, no rows.....*Dipodomys compactus* (Fig. 115)
Medullar "cells" form 2 columns, most rows fused.....*Reithrodontomys humulis* (Fig. 125)

17. Shaft d=90µm.....*Ondatra zibethicus* (Fig. 149)
Shaft d<90µm.....18

18. Medulla forms 2 columns.....19
Medulla forms more than 2 columns.....20

19. Shaft d=60µm.....*Peromyscus gossypinus* (Fig. 131)
Shaft d=30µm.....*Peromyscus leucopus* (Fig. 132)

20. Medulla forms 3 columns.....22
Medulla forms 4 columns.....21

21. Shaft d=80µm.....*Dipodomys spectabilis* (Fig. 119)
Shaft d=40µm.....*Dipodomys elator* (Fig. 116)

22. Shaft d>70µm.....*Oryzomys couesi* (Fig. 122)
Shaft d<70µm.....23

23. Shaft 50<d<70µm.....*Cratogeomys castanops* (Fig. 108)
Shaft d<40µm.....*Dipodomys merriami* (Fig. 117)

24. Medulla flattened (Fig. 3).....25
Medulla mixed ovate and flattened (Fig. 3).....55

25. Scales ovate (Fig. 7a).....26
Scales other than ovate (Fig. 7).....28

26. Medulla forms 3 columns.....*Geomys texensis* (Fig. 107)
Medulla does not form columns.....27

27. Shaft d<30µm.....*Peromyscus eremicus* (Fig. 130)
Shaft d>40µm.....*Mus musculus* (Fig. 152)

28. Scales elongate (Fig. 7c).....29
Scales other than elongate (Fig. 7).....33

29. Scales with simple pattern.....31
Scales with mixed V and W pattern.....30

30. Medulla forms 2 columns with rough edges.....*Reithrodontomys montanus* (Fig. 127)
Medulla forms 4 columns.....*Microtus pinetorum* (Fig. 148)

31. Medulla forms 2 columns.....32
Medulla forms 3 columns.....*Peromyscus boylii* (Fig. 129)

32. Shaft d>20µm.....*Thomomys bottae* (Fig. 101)
Shaft d<10µm.....*Onychomys arenicola* (Fig. 138)

33. Scales crenate (Fig. 7d).....34
Scales flattened (Fig. 7e).....49

34. Shaft d≥90µm.....35
Shaft d<90µm.....36

35. Scales smooth and long, giving appearance of elephant skin.....*Chaetodipus hispidus* (Fig. 113)
Rows of scales irregular.....*Spermophilus tridecemlineatus* (Fig. 95)

36. Shaft 50<d<70µm.....37
Shaft d<50µm.....41

37. Medullar columns disturbed.....*Sigmodon hispidus* (Fig. 141)
Medullar columns not disturbed.....38

38. Medulla forms 2 undisturbed columns.....*Reithrodontomys megalotis* (Fig. 126)
Medulla forms more than 2 undisturbed columns.....39

39. Medulla forms 3 undisturbed columns.....*Geomys bursarius* (Fig. 104)
Medulla forms more than 3 undisturbed columns.....40

40. Scales smooth, 1-2 scales/row, medulla sometimes visible on cuticular photograph.....*Perognathus flavescens* (Fig. 109)
Scales wavy, 1-3 scales/row.....*Microtus mexicanus* (Fig. 146)

41. All rows in medulla heavily fused.....*Geomys arenarius* (Fig. 103)
Not all rows in medulla fused.....42

42. Medulla forms 2 columns.....43
Medulla forms more than 2 columns.....47

43. Medulla forms mix of 2 and 3 columns.....*Neotoma micropus* (Fig. 145)
Medulla forms 2 columns.....44

44. Cortical intrusions give appearance of 2 extra columns at edges of shaft.....*Reithrodontomys fulvescens* (Fig. 124)
No cortical intrusions present.....45

45. Scales wavy.....*Peromyscus truei* (Fig. 135)
Scales smooth.....46

46. Shaft 40<d<50µm.....*Baiomys taylori* (Fig. 137)
Shaft d<40µm.....*Peromyscus pectoralis* (Fig. 134)

47. Medulla forms mix of 3 and 4 columns.....*Geomys knoxjonesi* (Fig. 105)
Medulla forms 3 columns.....48

48. Rows formed.....*Perognathus merriami* (Fig. 111)
Rows not formed.....*Perognathus flavus* (Fig. 110)

49. Shaft d>100µm.....50
Shaft d<100µm.....51

50. Shaft d=113µm.....*Chaetodipus intermedius* (Fig. 113)
Shaft d=121µm.....*Chaetodipus nelsoni* (Fig. 114)

51. Medullar columns disturbed or absent.....52
Medullar columns formed and undisturbed.....53

52. Shaft 90<d<100µm.....*Sigmodon fulviventer* (Fig. 140)
Shaft d<60µm.....*Neotoma floridana* (Fig. 143)

53. Shaft 80<d<100µm.....*Geomys personatus* (Fig. 106)
Shaft d<80µm.....54

54. Shaft d=72µm.....*Geomys breviceps* (Fig. 103)
Shaft d=54µm.....*Oryzomys palustris* (Fig. 123)

55. Scales crenate (Fig. 7d).....*Microtus ochrogaster* (Fig. 147)
Scales elongate (Fig. 7c).....56

56. Medulla forms 5 columns, shaft d=28.....*Dipodomys ordii* (Fig. 118)
Medulla forms 1 column, shaft d=62.....*Neotoma mexicana* (Fig. 146)

57. Medulla nodose type a (Fig. 5a).....58
Medulla nodose type b (Fig. 5b).....60

58. Scales crenate (Fig. 7d).....*Glaucomys volans* (Fig. 100)
Scales flattened (Fig. 7e).....59

59. Medullar "cells" flattened.....*Myocastor coypus* (Fig. 154)
Medulla disrupted with cortical intrusions.....*Cynomys ludovicianus* (Fig. 97)

60. Medulla disturbed.....*Sciurus caroliensis* (Fig. 98)
Medulla undisturbed.....61

61. Scales flattened (Fig. 7e).....*Spermophilus mexicanus* (Fig. 93)
Scales crenate (Fig. 7d).....62

62. Shaft d>100µm.....*Spermophilus spilosoma* (Fig. 94)
Shaft d<100µm.....63

63. Shaft 70<d<100µm, scales smooth.....*Sciurus niger* (Fig. 99)
Shaft d<60µm, scales wavy.....*Tamias canipes* (Fig. 91)

Family Sciuridae

***Tamias canipes* - Gray-footed Chipmunk** (TCWC 48007)

Medulla continuous, nodose type b, unordered, undisturbed, flattened, some places appear to be arranged in columns. Cuticula imbricate, crenate, with wavy and irregular rows. Midshaft dia. 53µm.

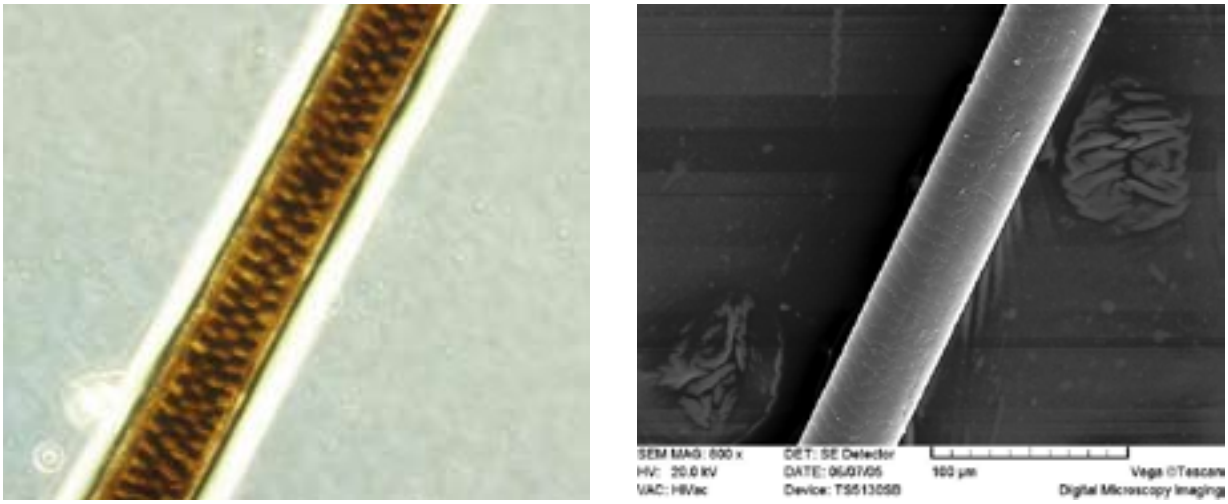

Figure 91. Medulla (left) and cuticula (right) of *Tamias canipes*.

***Ammospermophilus interpres* - Texas Antelope Squirrel** (SHM 98)

Medulla discontinuous, fragmental type b, mostly covered by cortical intrusions. Cuticula imbricate, crenate, with wavy and irregular rows. Midshaft dia. 95µm.

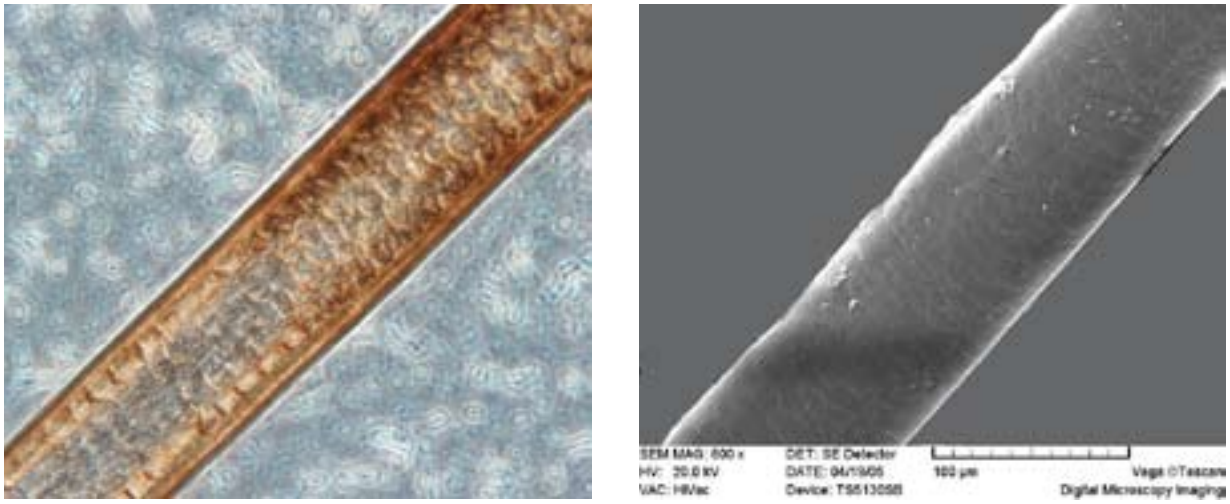

Figure 92. Medulla (left) and cuticula (right) of *Ammospermophilus interpres.*

***Spermophilus mexicanus* - Mexican Ground Squirrel** (SHM 88)

Medulla continuous, nodose type b, unordered, undisturbed, flattened, mosaic, and occupies more than 1/2 of shaft. Cuticula imbricate, flattened, rows regular but distorted on the edges. Midshaft dia. 138µm.

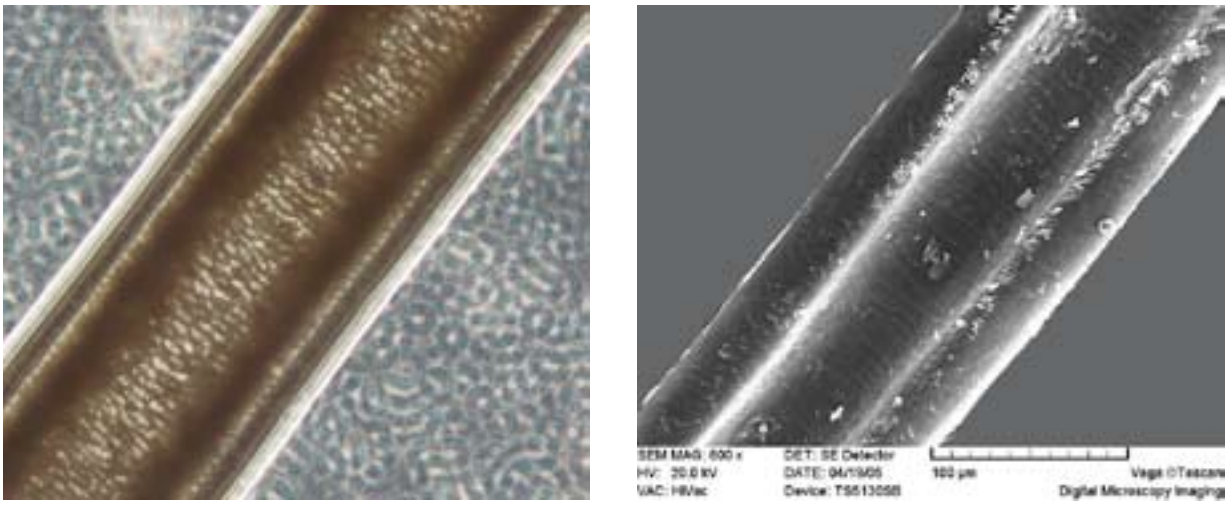

Figure 93. Medulla (left) and cuticula (right) of *Spermophilus mexicanus.*

***Spermophilus spilosoma* - Spotted Ground Squirrel** (ASNHC 5029)

Medulla continuous, nodose type b, unordered, undisturbed, flattened, mosaic, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, scales and rows wavy and irregular. Midshaft dia. 135µm.

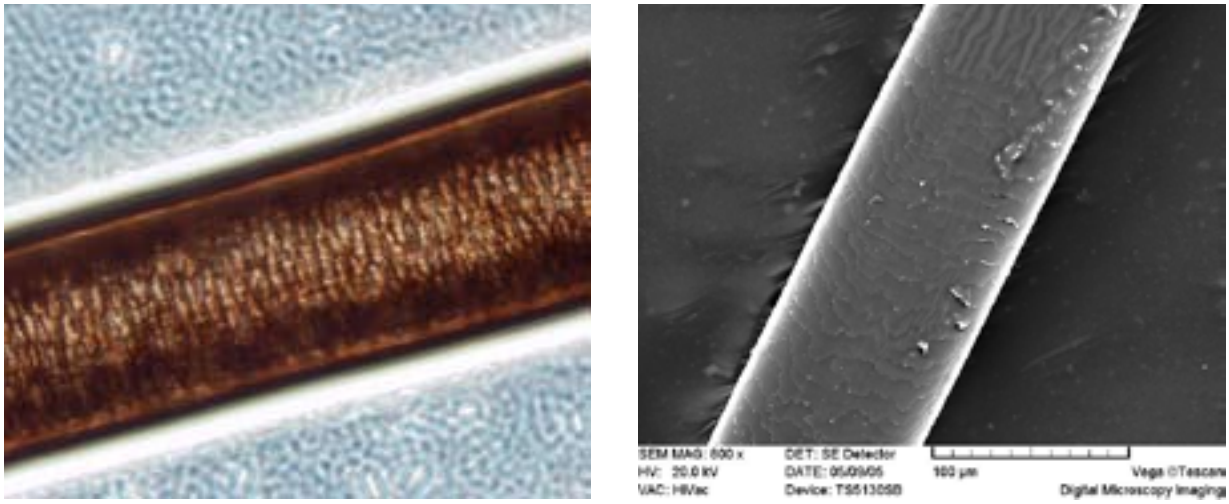

Figure 94. Medulla (left) and cuticula (right) of *Spermophilus spilosoma.*

***Spermophilus tridecemlineatus* - Thirteen-lined Ground Squirrel** (SHM 211)

Medulla discontinuous, compound, flattened, multiple columns with some rows fused. Cuticula imbricate, crenate, with irregular rows. Midshaft dia. 90µm.

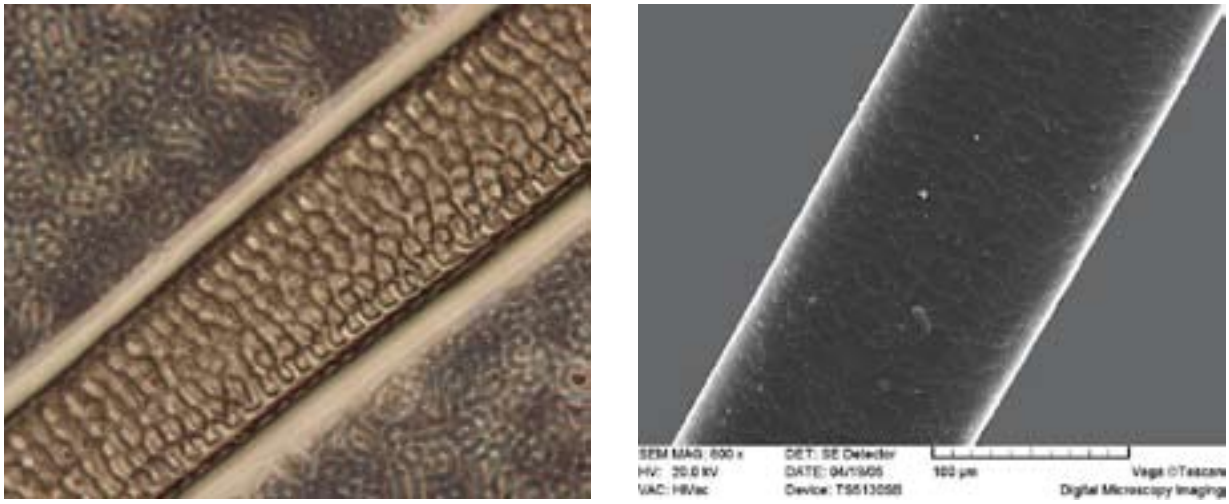

Figure 95. Medulla (left) and cuticula (right) of *Spermophilus tridecemlineatus.*

***Spermophilus variegatus* - Rock Squirrel** (SHM 183)

Medulla discontinuous, fragmental type c, with cortical intrusions that are broken only in the center. Cuticula imbricate, flattened, smooth scales, mostly one scale per row. Midshaft dia. 110µm.

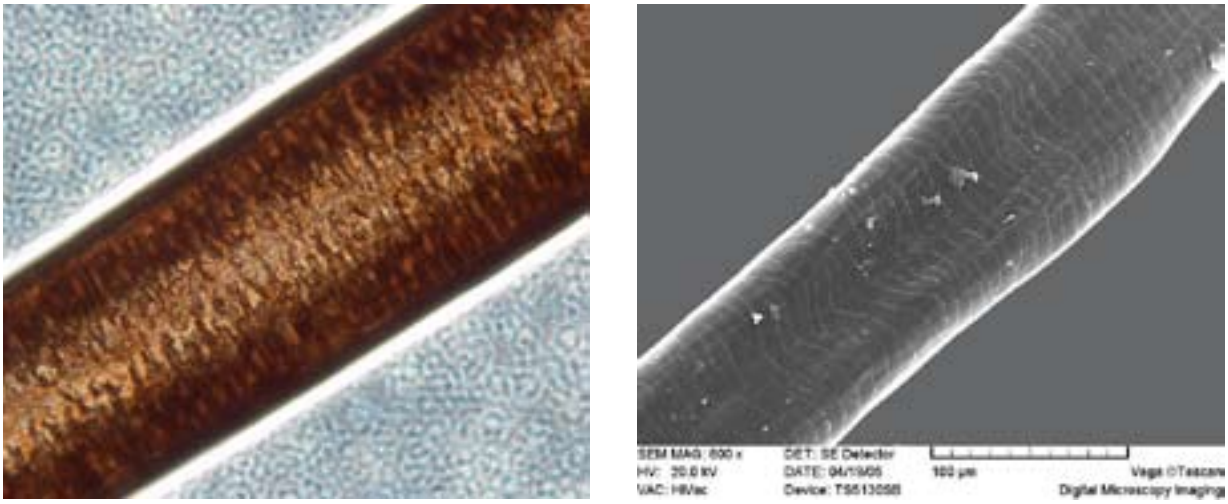

Figure 96. Medulla (left) and cuticula (right) of *Spermophilus variegatus.*

***Cynomys ludovicianus* - Black-tailed Prairie Dog** (SHM 288)

Medulla continuous, nodose type a, disrupted, cortical intrusions, and occupies more than 1/2 of shaft. Cuticula imbricate, flattened, with very wavy and irregular scales and rows. Midshaft dia. 125µm.

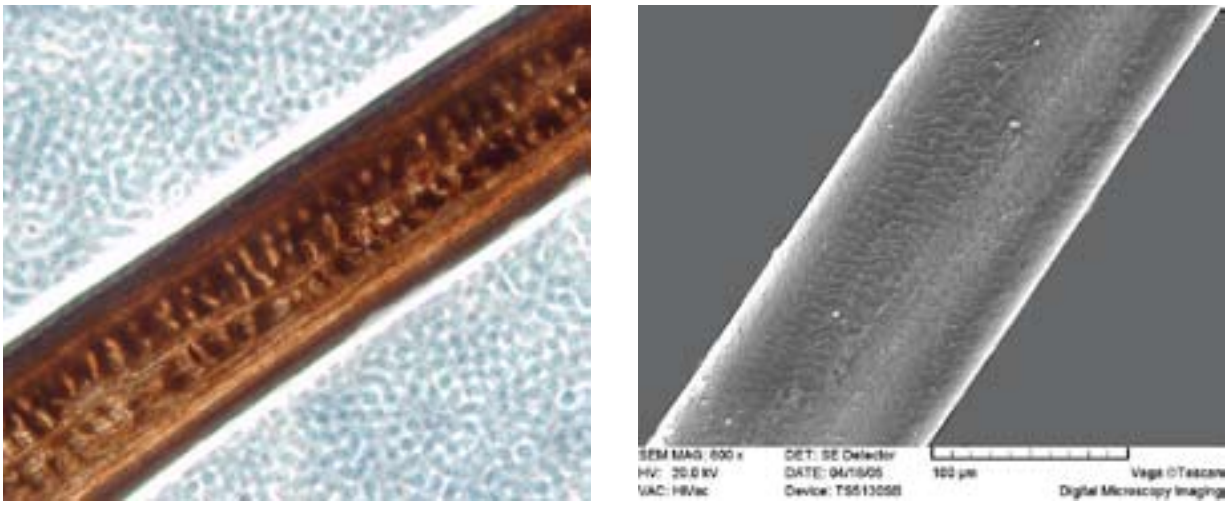

Figure 97. Medulla (left) and cuticula (right) of *Cynomys ludovicianus.*

***Sciurus caroliensis* - Eastern Gray Squirrel** (SHM 689)

Medulla continuous, nodose type b, unordered, disturbed, flattened with cortical intrusions on the edges, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, with wavy and broken rows. Midshaft dia. 76µm.

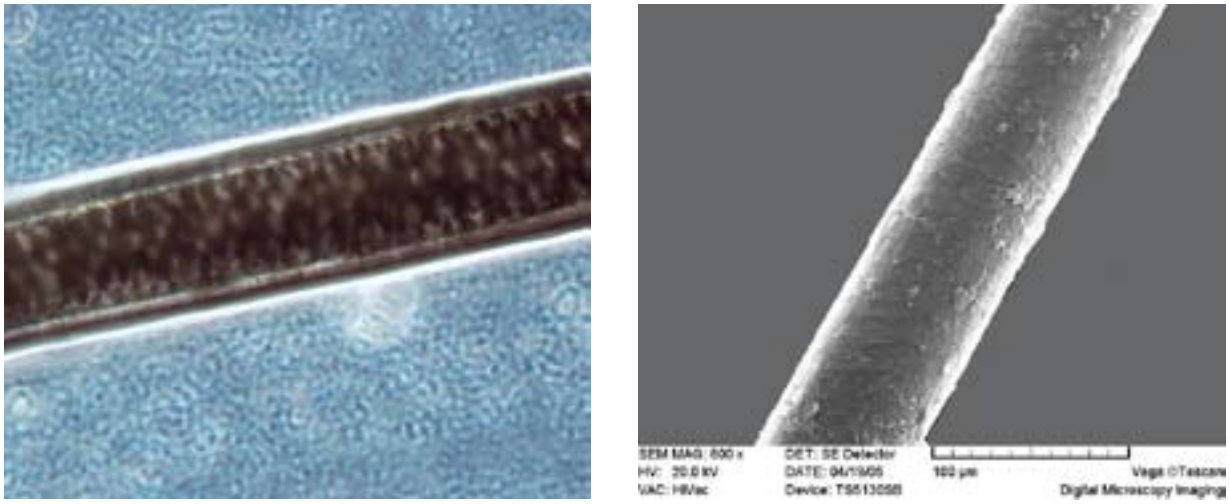

Figure 98. Medulla (left) and cuticula (right) of *Sciurus caroliensis*.

***Sciurus niger* - Eastern Fox Squirrel** (SHM 318)

Medulla continuous, nodose type b, unordered, undisturbed, flattened, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, scales smooth, 1-3 scales/row. Midshaft dia. 78µm.

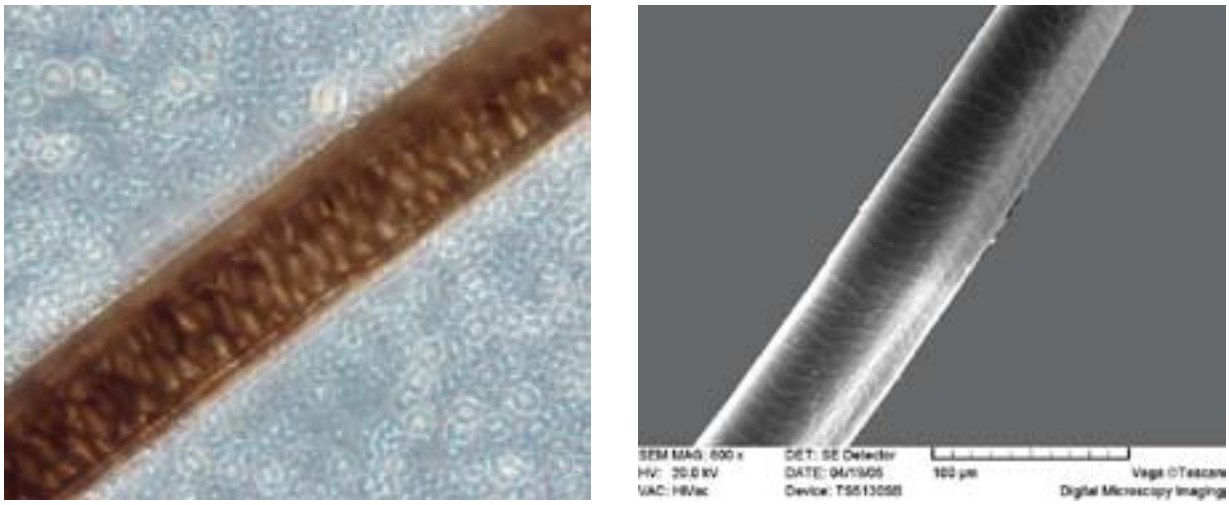

Figure 99. Medulla (left) and cuticula (right) of *Sciurus niger*.

***Glaucomys volans* - Southern Flying Squirrel** (SHM 369)

Medulla continuous, nodose type a, and occupies most of shaft. Cuticula imbricate, crenate, smooth scales, 1-3 scales/row. Midshaft dia. 50µm.

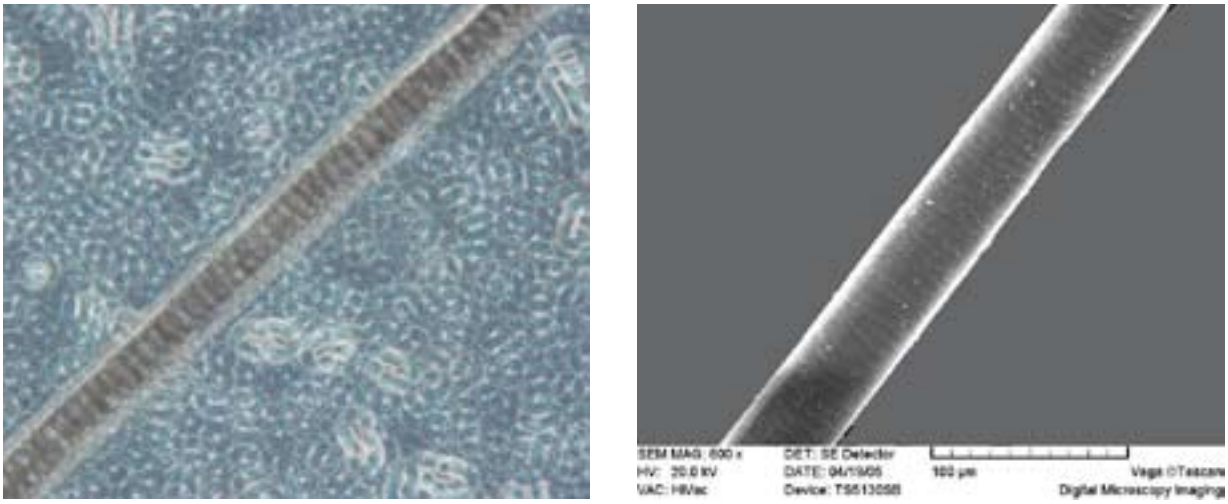

Figure 100. Medulla (left) and cuticula (right) of *Glaucomys volans.*

Family Geomyidae

***Thomomys bottae* - Botta's Pocket Gopher** (ASNHC 8677)

Medulla discontinuous, compound, flattened, 2 columns of "cells", most rows fused. Cuticula imbricate, elongate, with smooth scales. Midshaft dia. 26µm.

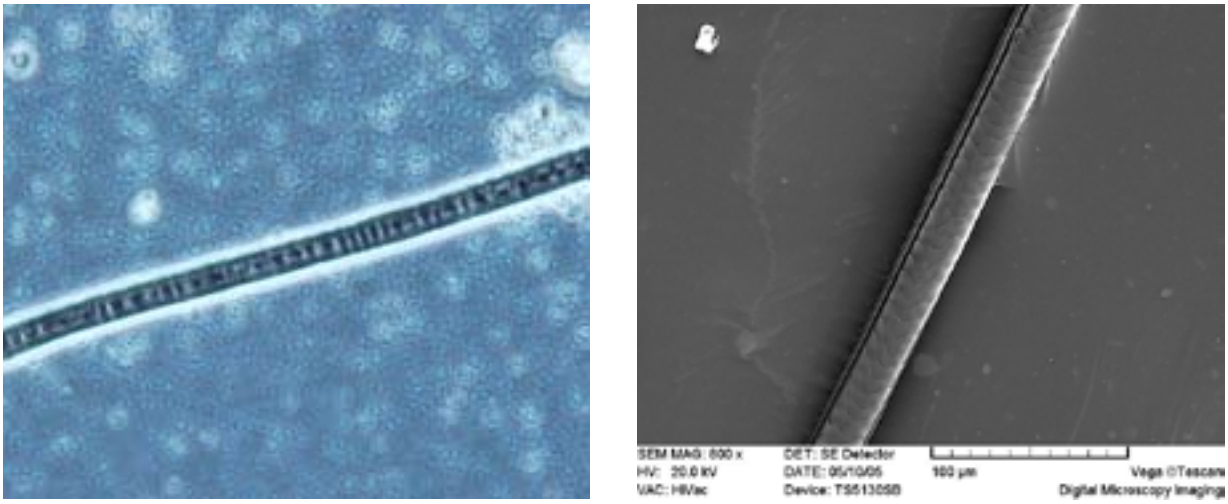

Figure 101. Medulla (left) and cuticula (right) of *Thomomys bottae.*

***Geomys arenarius* - Desert Pocket Gopher** (ASNHC 7740)

Medulla discontinuous, compound, flattened, rows heavily fused. Cuticula imbricate, crenate, long scales with wavy rows. Midshaft dia. 40µm.

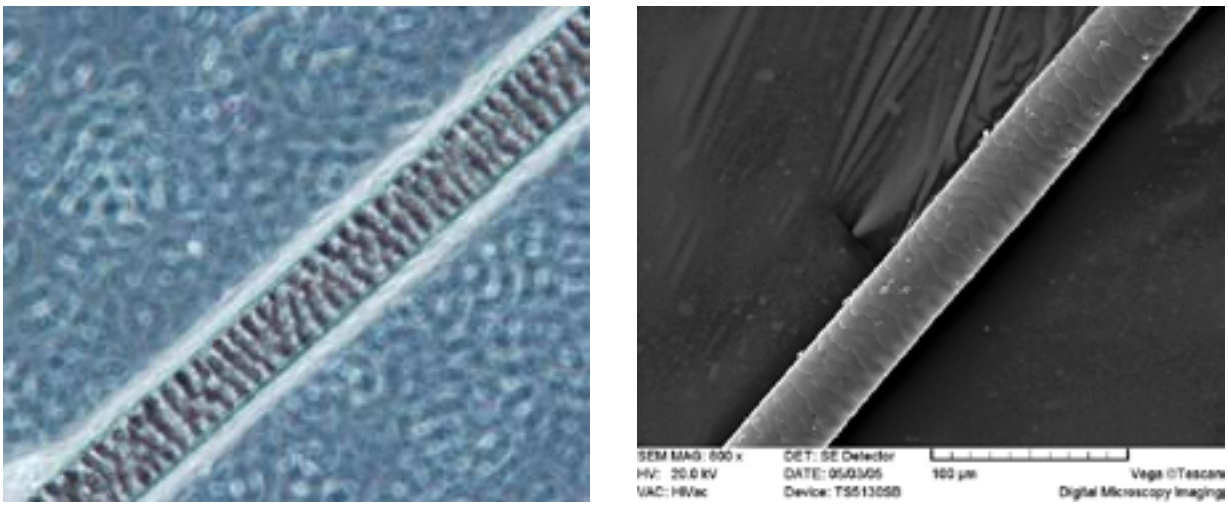

Figure 102. Medulla (left) and cuticula (right) of *Geomys arenarius*.

***Geomys breviceps* - Baird's Pocket Gopher** (SHM 153)

Medulla discontinuous, compound, flattened, 3 columns, some rows fused. Cuticula imbricate, flattened, very wavy and irregular. Midshaft dia. 72µm.

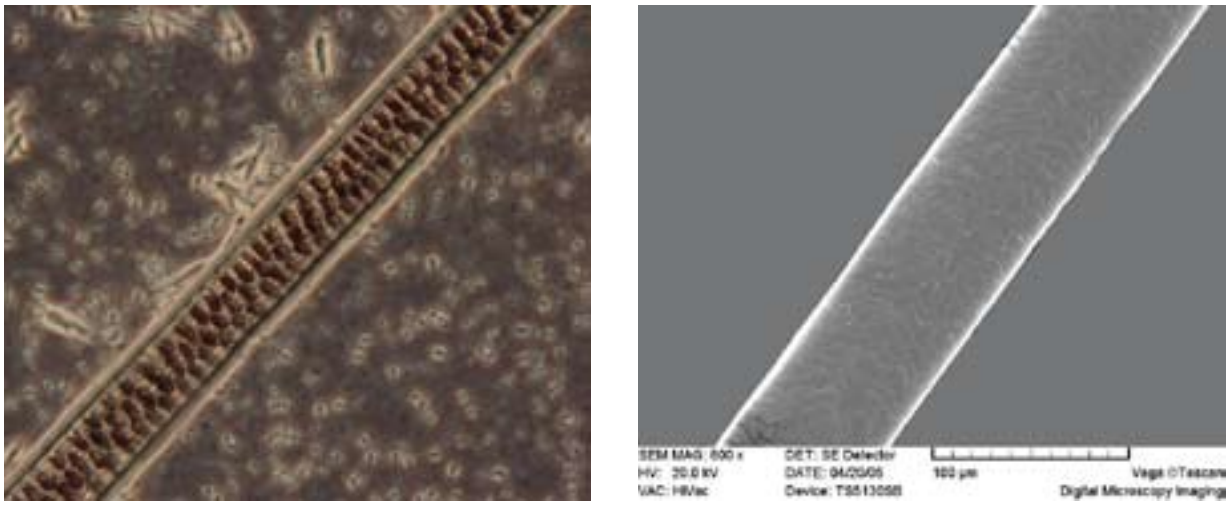

Figure 103. Medulla (left) and cuticula (right) of *Geomys breviceps*.

***Geomys bursarius* - Plains Pocket Gopher** (SHM 383)

Medulla discontinuous, compound, flattened, 3 columns, non-fused rows. Cuticula imbricate, crenate, smooth scales, 1-2 scales/row. Midshaft dia. 52µm.

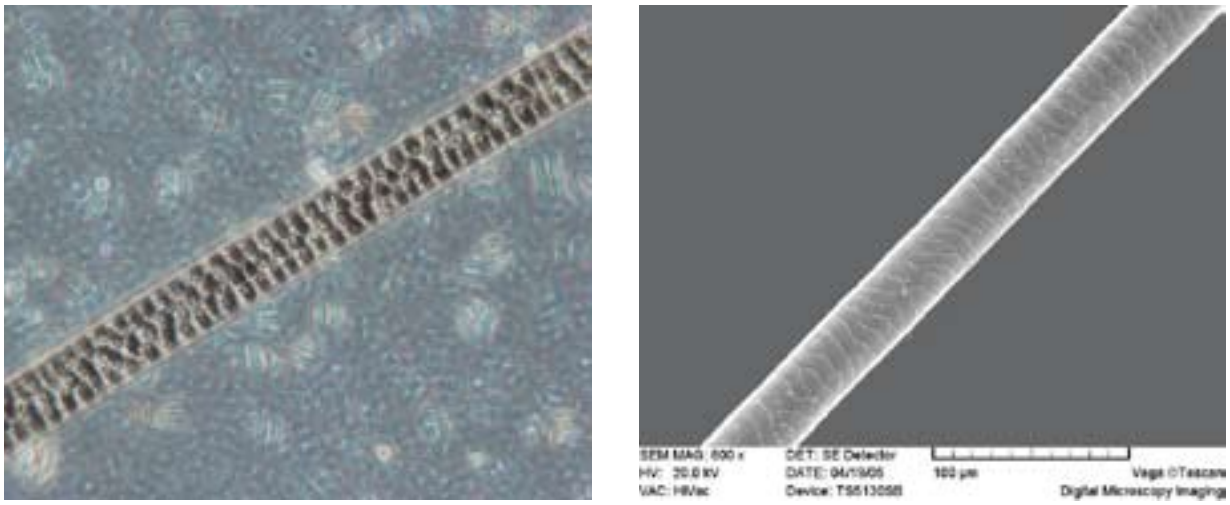

Figure 104. Medulla (left) and cuticula (right) of *Geomys bursarius*.

***Geomys knoxjonesi* - Jones' Pocket Gopher** (ASNHC 970)

Medulla discontinuous, compound, flattened, 3-4 columns, some rows partially fused. Cuticula imbricate, crenate, 1-2 scales/row with irregular rows. Midshaft dia. 36µm.

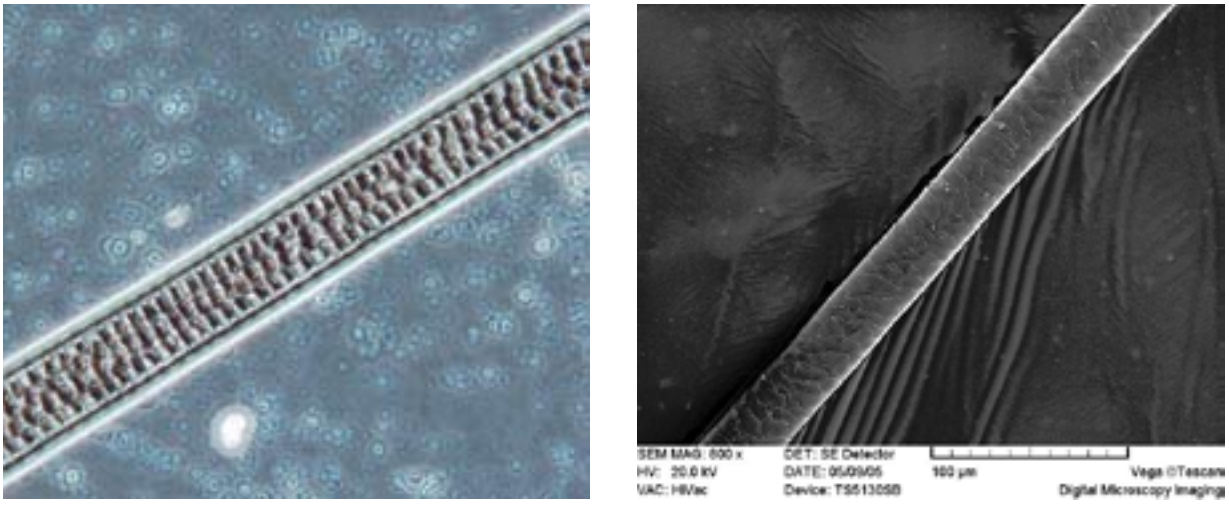

Figure 105. Medulla (left) and cuticula (right) of *Geomys knoxjonesi*.

***Geomys personatus* - Texas Pocket Gopher** (ASNHC 11391)

Medulla discontinuous, compound, flattened, with most rows fused. Cuticula imbricate, flattened, with wavy and irregular scales and rows. Midshaft dia. 85µm.

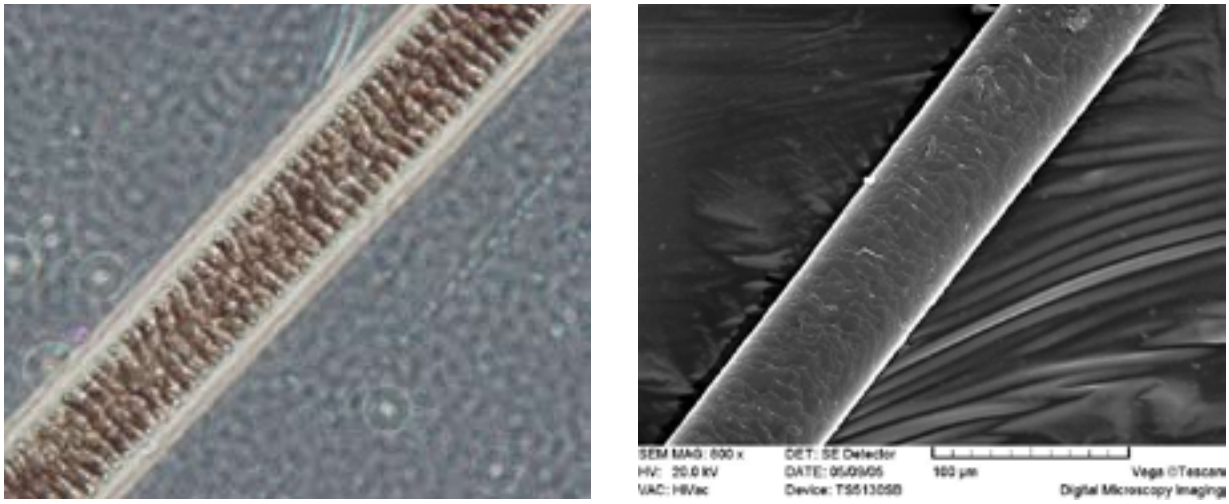

Figure 106. Medulla (left) and cuticula (right) of *Geomys personatus*.

***Geomys texensis* - Llano Pocket Gopher** (ASNHC 10939)

Medulla discontinuous, compound, flattened, 3 columns, rows formed. Cuticula imbricate, ovate, with visible medulla. Midshaft dia. 34µm.

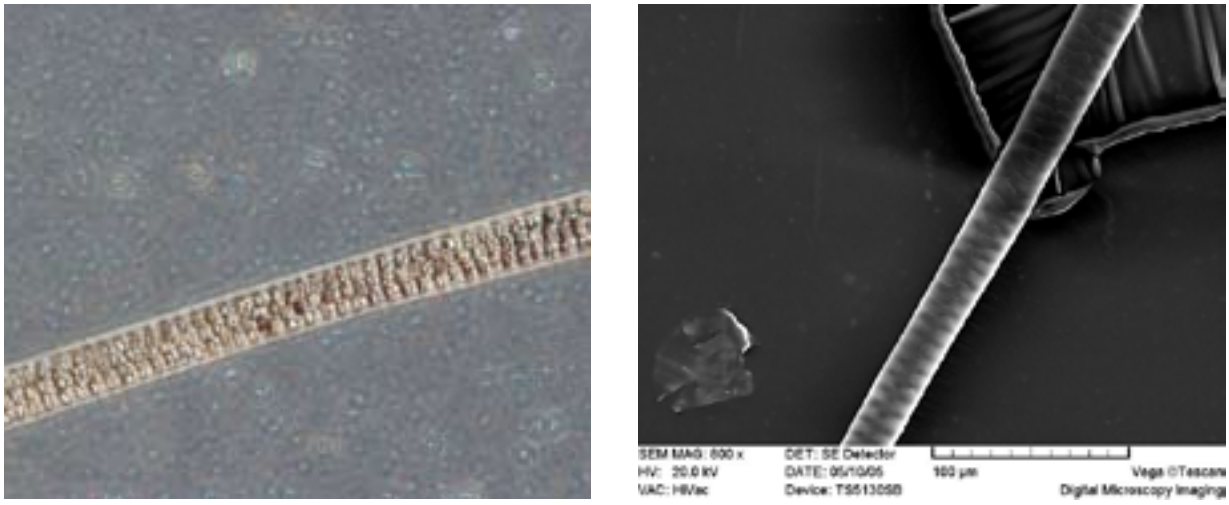

Figure 107. Medulla (left) and cuticula (right) of *Geomys texensis*.

***Cratogeomys castanops* - Yellow-faced Pocket Gopher** (SHM 99)

Medulla discontinuous, compound, ovate, 3 columns, some rows appear, rows not fused. Cuticula imbricate, crenate, small scales with wavy rows. Midshaft dia. 58µm.

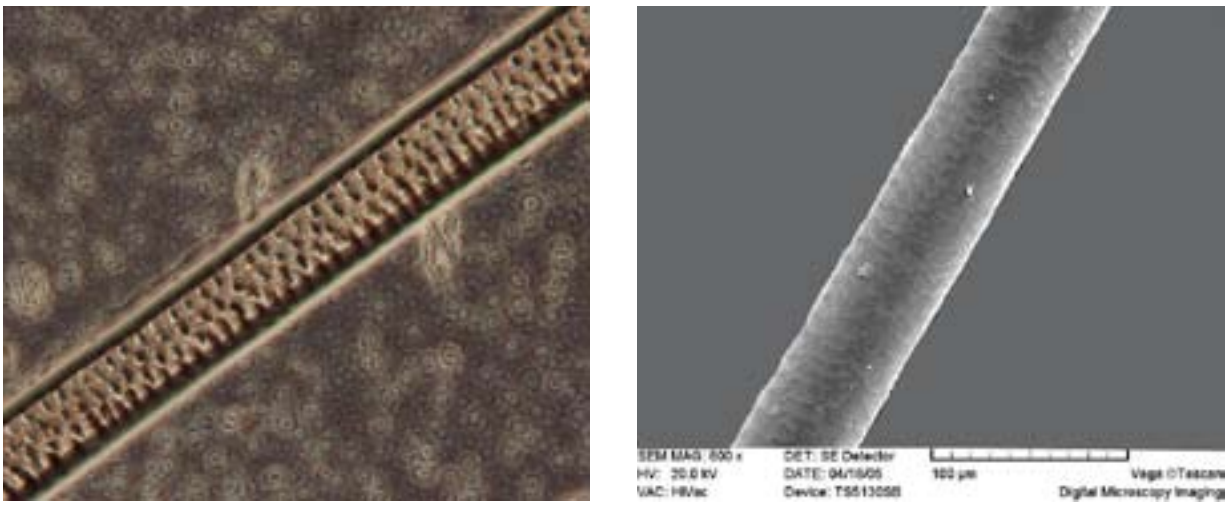

Figure 108. Medulla (left) and cuticula (right) of *Cratogeomys castanops*.

Family Heteromyidae

***Perognathus flavescens* - Plains Pocket Mouse** (ASNHC 3635)

Medulla discontinuous, compound, flattened, more than 4 columns, with rows formed and mostly fused. Cuticula imbricate, crenate, smooth scales, 1-2 scales/rows, medulla apparent in some places. Midshaft dia. 60µm.

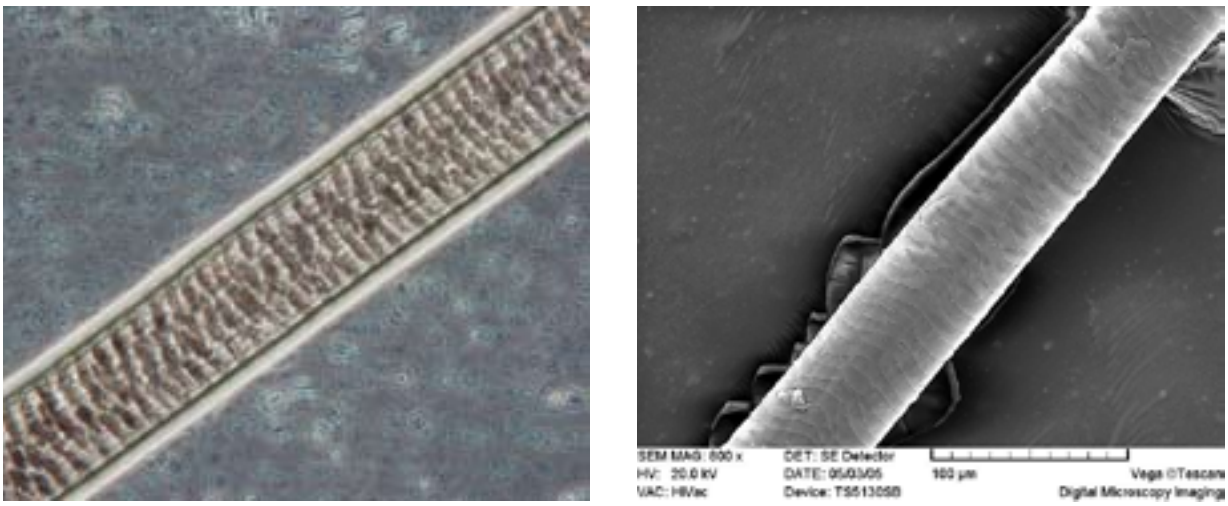

Figure 109. Medulla (left) and cuticula (right) of *Perognathus flavescens.*

***Perognathus flavus* - Silky Pocket Mouse** (ASNHC 3713)

Medulla discontinuous, compound, flattened, 3 columns, no rows formed, and occupies entire shaft. Cuticula imbricate, crenate, smooth scales, 1-2 long scales/row, medulla somewhat visible. Midshaft dia. 45µm.

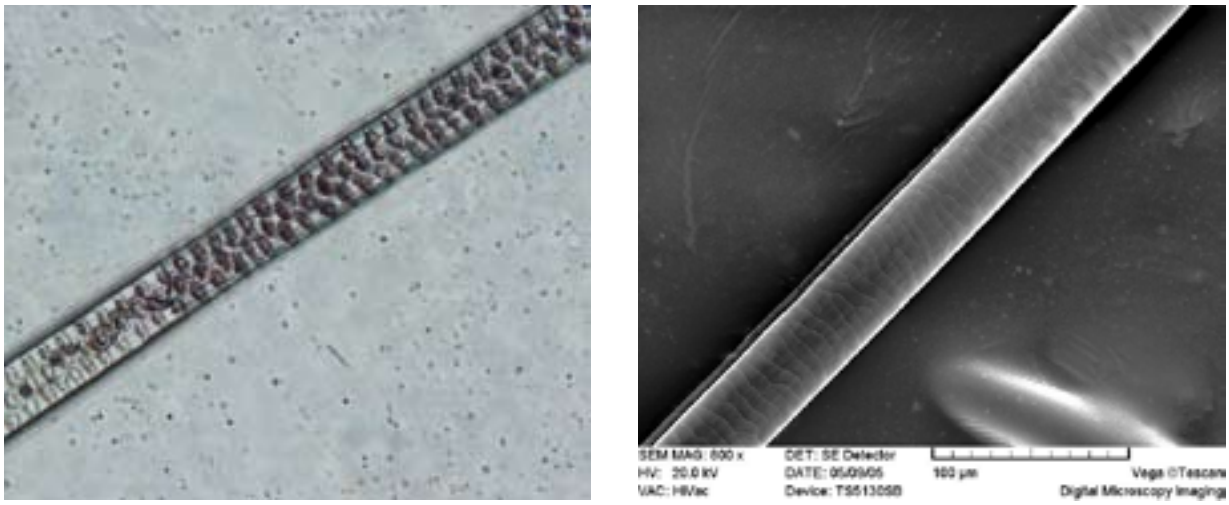

Figure 110. Medulla (left) and cuticula (right) of *Perognathus flavus.*

***Perognathus merriami* - Merriam's Pocket Mouse** (SHM 704)

Medulla discontinuous, compound, flattened, 3 columns, rows formed but not fused. Cuticula imbricate, crenate, rows curved and parallel, medulla visible. Midshaft dia. 45µm.

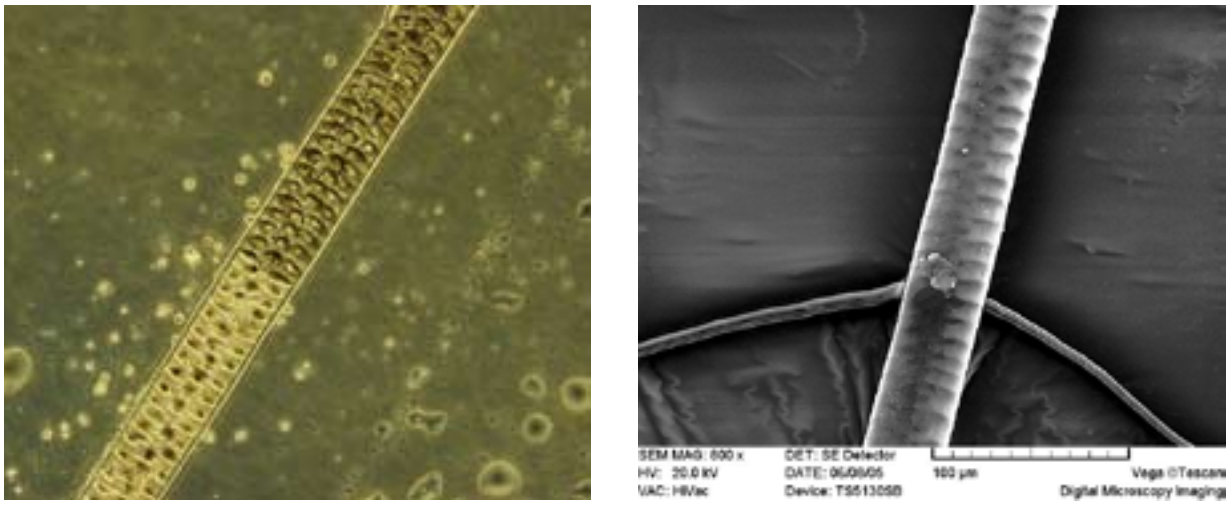

Figure 111. Medulla (left) and cuticula (right) of *Perognathus merriami.*

***Chaetodipus hispidus* - Hispid Pocket Mouse** (SHM 25)

Medulla discontinuous, compound, flattened, more than 3 columns, rows not formed. Cuticula imbricate, crenate, with long smooth scales, elephant skin-like. Midshaft dia. 96µm.

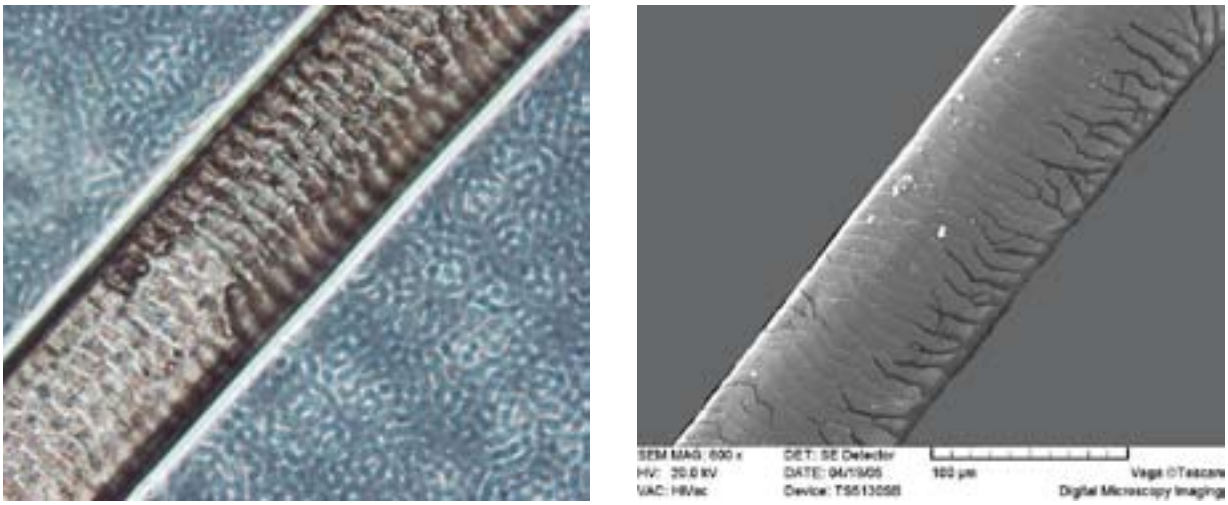

Figure 112. Medulla (left) and cuticula (right) of *Chaetodipus hispidus.*

***Chaetodipus intermedius* - Rock Pocket Mouse** (ASNHC 12113)

Medulla discontinuous, compound, flattened, more than 3 columns, rows formed. Cuticula imbricate, flattened, smooth scales with multiple scales/row. Midshaft dia. 113µm.

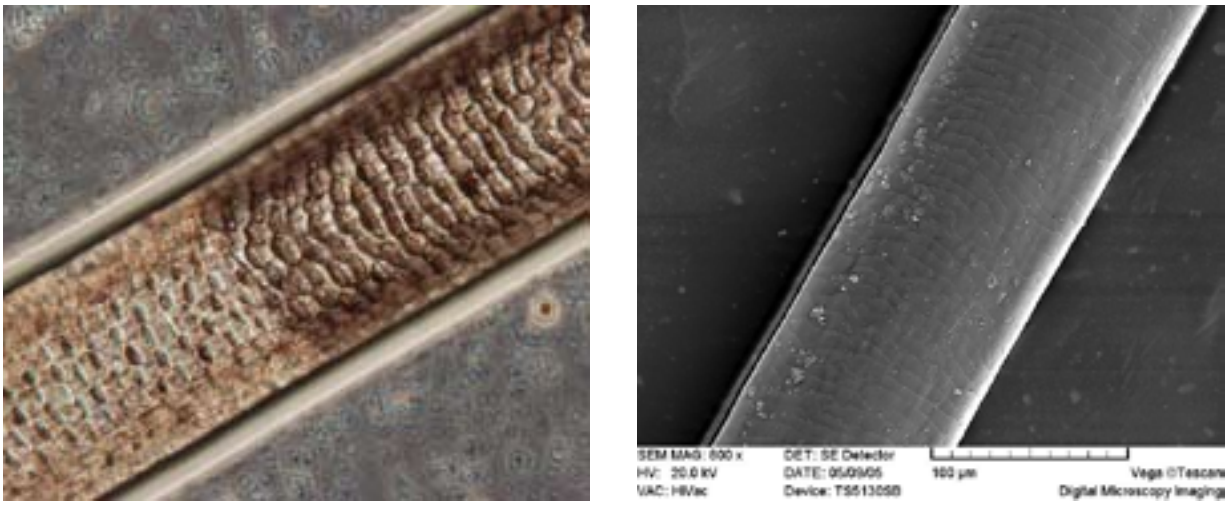

Figure 113. Medulla (left) and cuticula (right) of *Chaetodipus intermedius.*

***Chaetodipus nelsoni* - Nelson's Pocket Mouse** (ASNHC 9208)

Medulla discontinuous, compound, flattened, with more than 3 columns, some rows formed. Cuticula imbricate, flattened, smooth scales, multiple scales/row. Midshaft dia. 121µm.

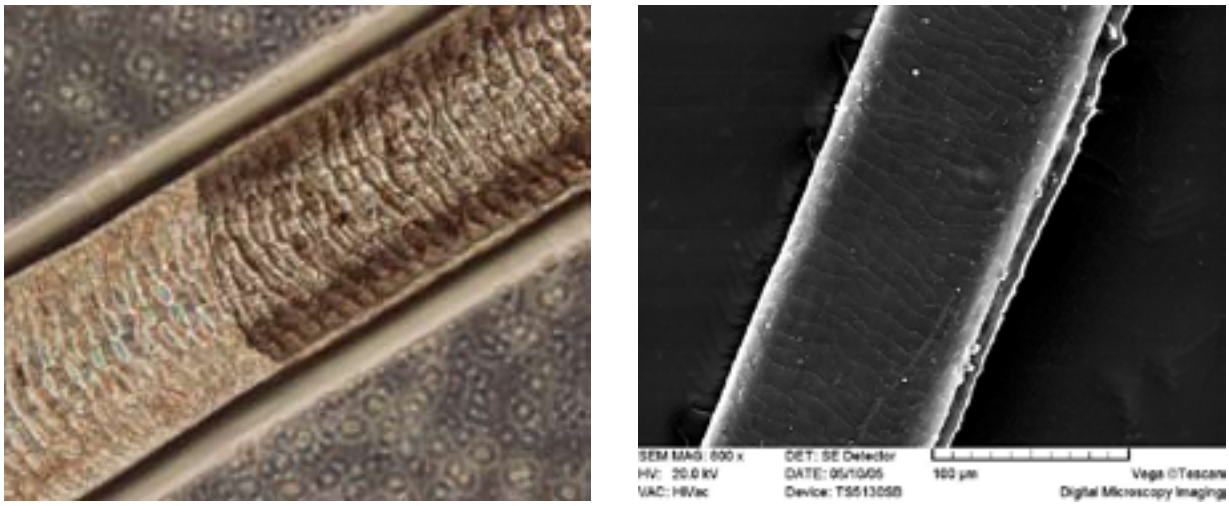

Figure 114. Medulla (left) and cuticula (right) of *Chaetodipus nelsoni.*

***Dipodomys compactus* - Gulf Coast Kangaroo Rat** (SHM 627)

Medulla discontinuous, compound, ovate, 3 columns, no rows formed, and occupies entire shaft. Cuticula imbricate, elongate, scales smooth, rows close and form V-pattern. Midshaft dia. 28µm.

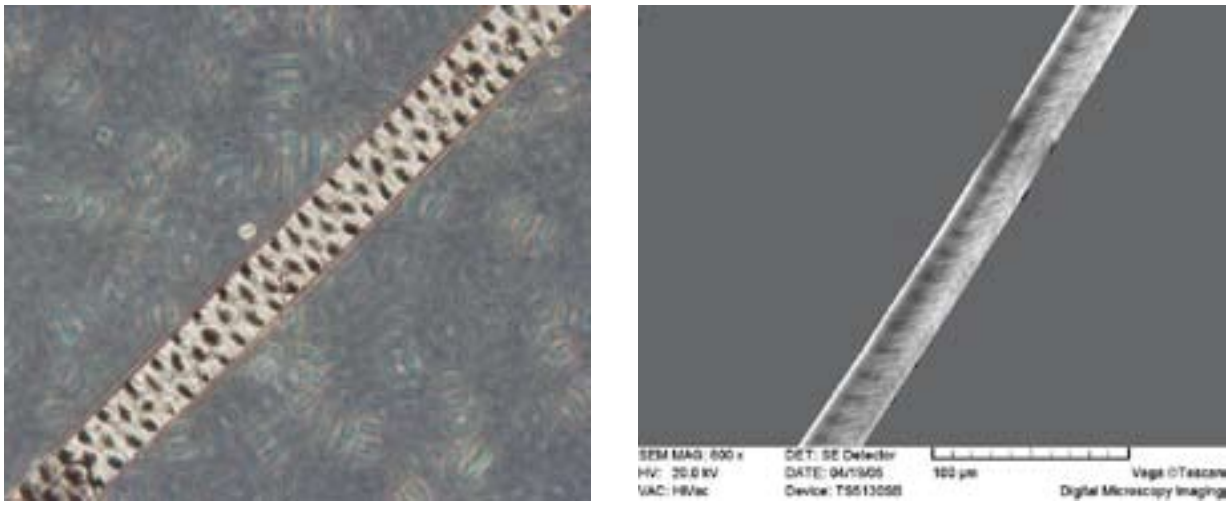

Figure 115. Medulla (left) and cuticula (right) of *Dipodomys compactus.*

***Dipodomys elator* - Texas Kangaroo Rat** (ASNHC 4306)

Medulla discontinuous, compound, ovate, 4 columns, no rows formed, mosaic arrangement. Cuticula imbricate, crenate, smooth scales, 1-3 scales/row. Midshaft dia. 40µm.

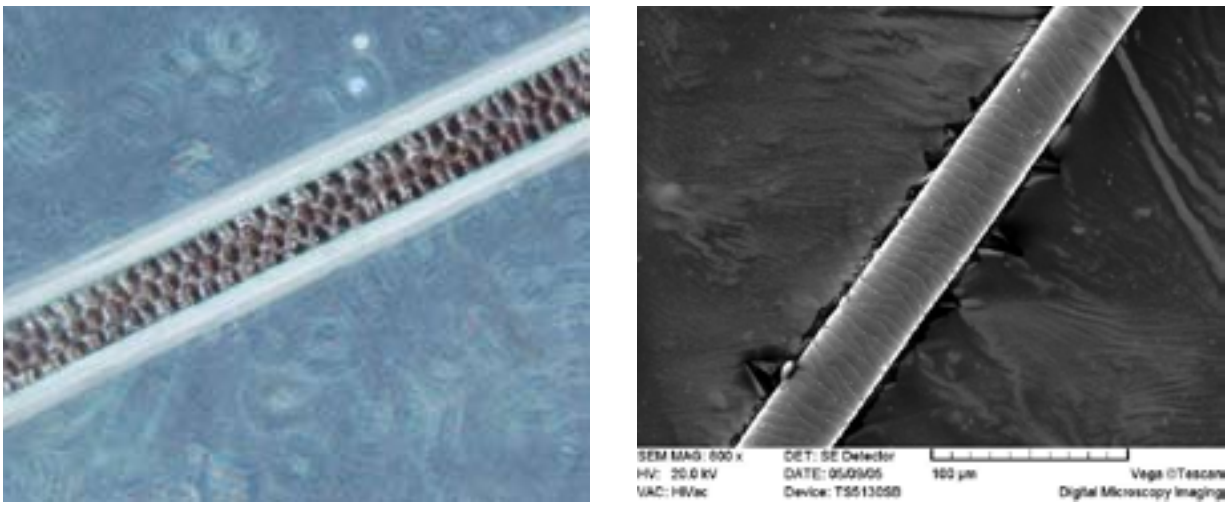

Figure 116. Medulla (left) and cuticula (right) of *Dipodomys elator*.

***Dipodomys merriami* - Merriam's Kangaroo Rat** (SHM 219)

Medulla discontinuous, compound, ovate, 3 columns, no rows formed, and occupies entire shaft. Cuticula imbricate, crenate, with V-pattern in some places. Midshaft dia. 34µm.

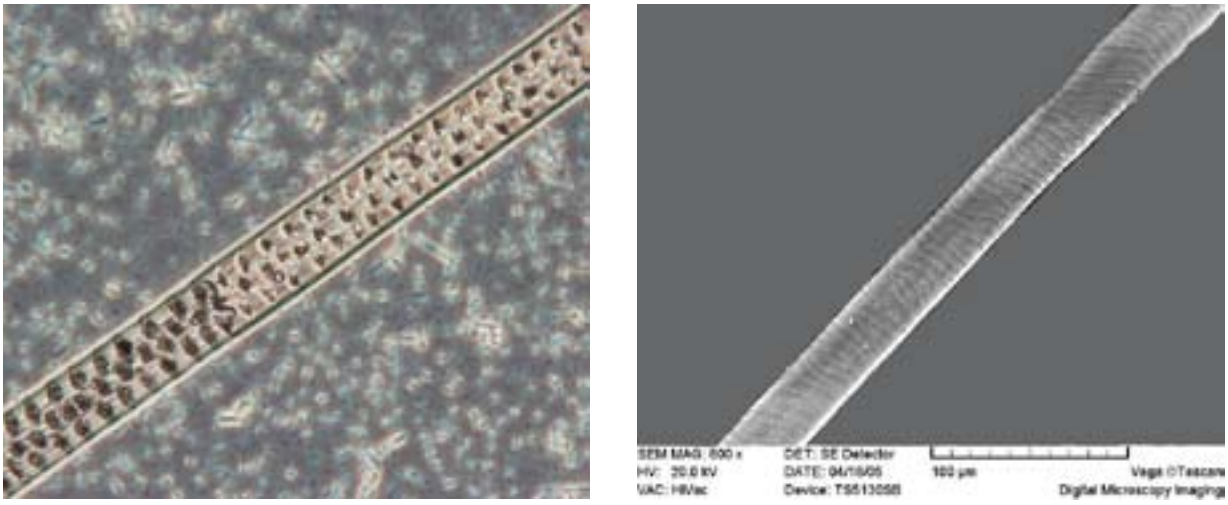

Figure 117. Medulla (left) and cuticula (right) of *Dipodomys merriami*.

***Dipodomys ordii* - Ord's Kangaroo Rat** (SHM 634)

Medulla discontinuous, compound, mixed ovate and flattened, 5 columns, central columns ovate, edge columns flattened, no rows. Cuticula imbricate, elongate, mixed V- and W-pattern. Midshaft dia. 28µm.

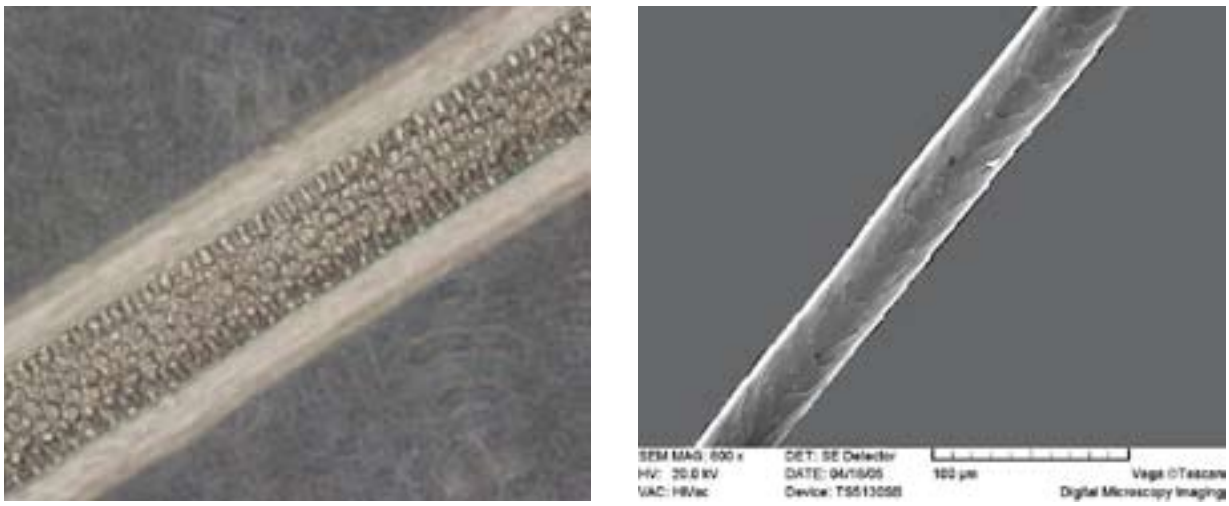

Figure 118. Medulla (left) and cuticula (right) of *Dipodomys ordii*.

***Dipodomys spectabilis* - Banner-tailed Kangaroo Rat** (SHM 172)

Medulla discontinuous, compound, ovate, 4 columns, completely unordered. Cuticula imbricate, crenate, smooth scales, 1-3 scales/row, often disturbed. Midshaft dia. 80µm.

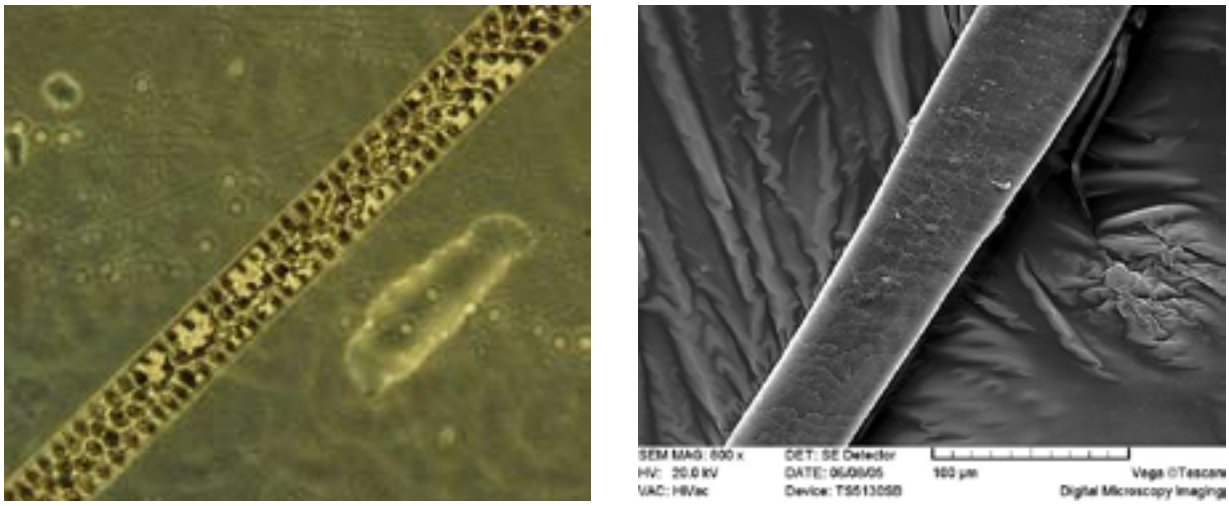

Figure 119. Medulla (left) and cuticula (right) of *Dipodomys spectabilis*.

***Liomys irroratus* - Mexican Spiny Pocket Mouse** (SHM 107)

Medulla discontinuous, fragmental type b, needle-like structures in central area. Cuticula imbricate, flattened, scales have wavy edges, with "large-wave" pattern of rows. Midshaft dia. 385µm.

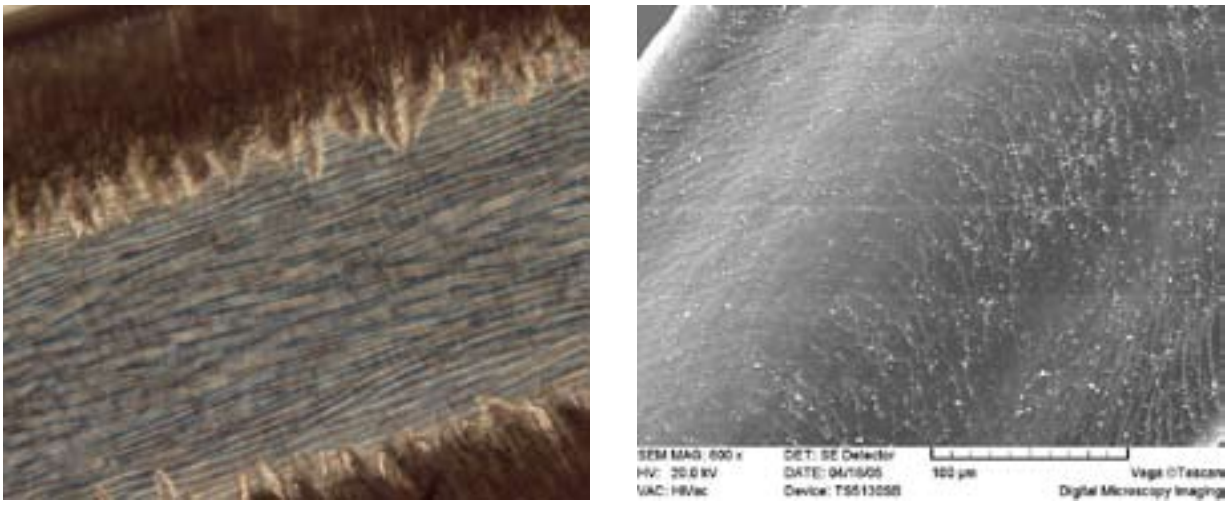

Figure 120. Medulla (left) and cuticula (right) of *Liomys irroratus.*

Family Castoridae

***Castor canadensis* - American Beaver** (SHM 303)

Medulla discontinuous, fragmental type a, cortical intrusions around medulla. Cuticula imbricate, crenate, with wavy scales and rows. Midshaft dia. 135µm.

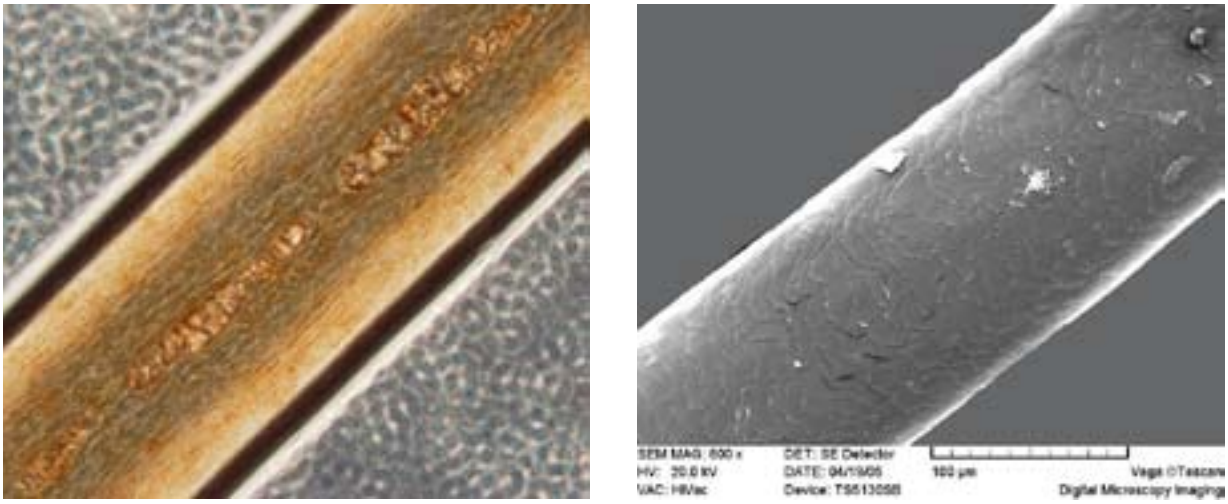

Figure 121. Medulla (left) and cuticula (right) of *Castor canadensis.*

Family Cricetidae

***Oryzomys couesi* - Coues' Rice Rat** (SHM 361)

Medulla discontinuous, compound, ovate, 3 columns, some rows fused, and occupies entire shaft. Cuticula imbricate, crenate, scales not smooth, rows wavy and irregular. Midshaft dia. 75µm.

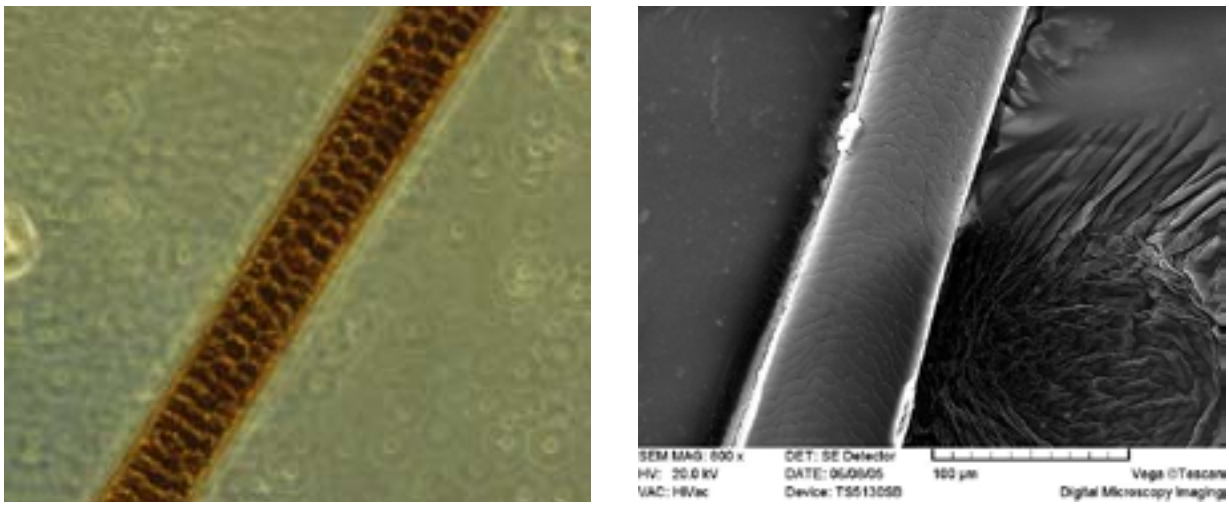

Figure 122. Medulla (left) and cuticula (right) of *Oryzomys couesi*.

***Oryzomys palustris* - Marsh Rice Rat** (SHM 63)

Medulla discontinuous, compound, flattened, 3 columns, some rows fused, and occupies entire shaft. Cuticula is imbricate, flattened, with wavy rows and edges, some V-pattern present. Midshaft dia. 54µm.

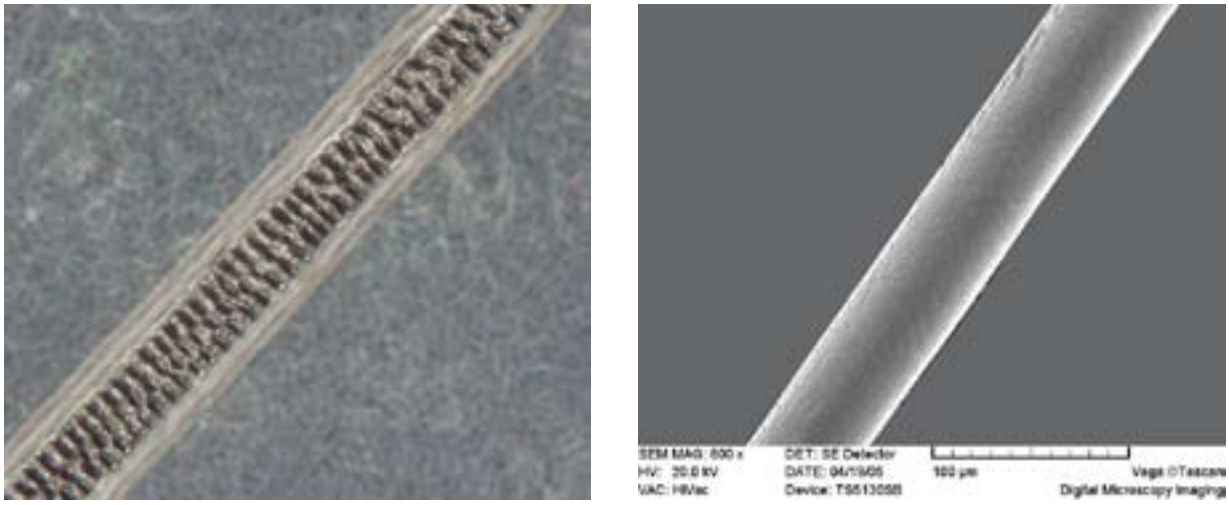

Figure 123. Medulla (left) and cuticula (right) of *Oryzomys palustris*.

***Reithrodontomys fulvescens* - Fulvous Harvest Mouse** (SHM 47)

Medulla discontinuous, compound, flattened, 2 columns in central part, no rows formed, cortical intrusions give appearance of 2 additional columns at the edges. Cuticula imbricate, crenate, smooth scales, 2-3 scales per row, rows parallel. Midshaft dia. 43µm.

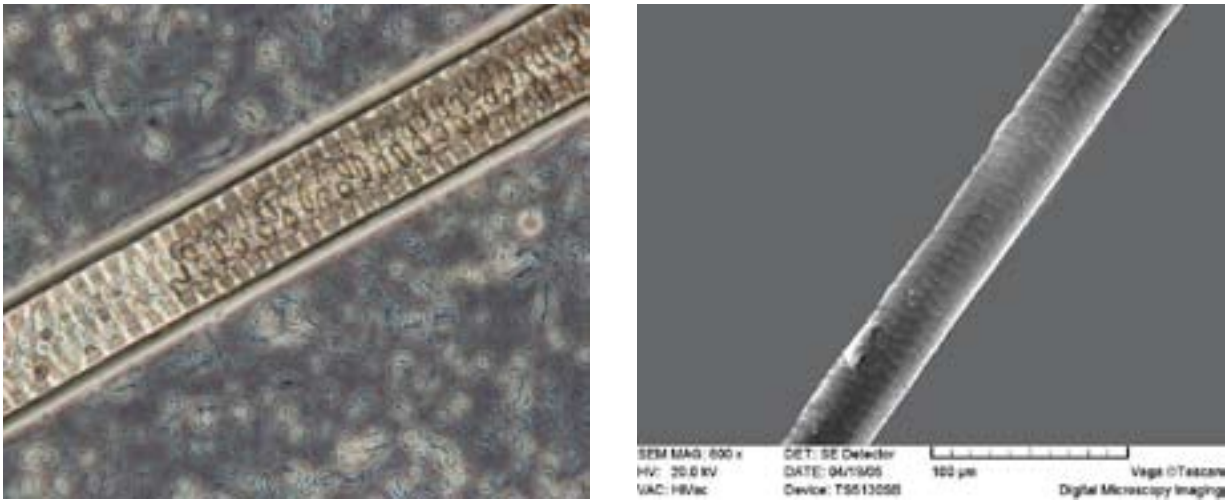

Figure 124. Medulla (left) and cuticula (right) of *Reithrodontomys fulvescens.*

***Reithrodontomys humulis* - Eastern Harvest Mouse** (SHM 131)

Medulla discontinuous, compound, ovate, 2 columns, most rows fused, and occupies more than 1/2 of shaft. Cuticula imbricate, elongate, scales not smooth and uniform, rows have mixed V- and W-pattern. Midshaft dia. 43µm.

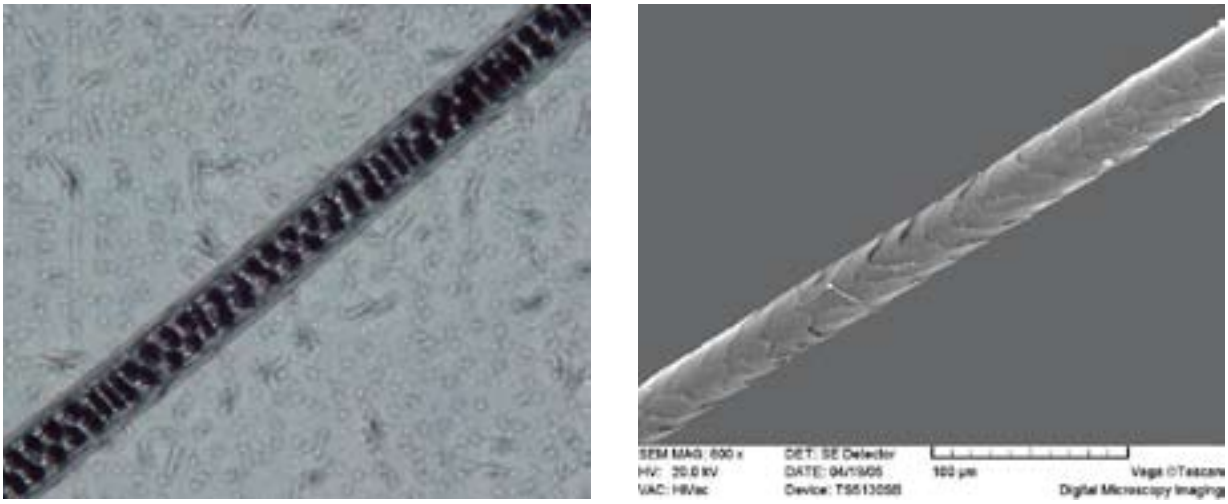

Figure 125. Medulla (left) and cuticula (right) of *Reithrodontomys humulis.*

***Reithrodontomys megalotis* - Western Harvest Mouse** (SHM 24)

Medulla discontinuous, compound, flattened, 2 columns, some rows fused, and occupies entire shaft. Cuticula imbricate, crenate, smooth scales, 1-3 scales/row, rows parallel. Midshaft dia. 56µm.

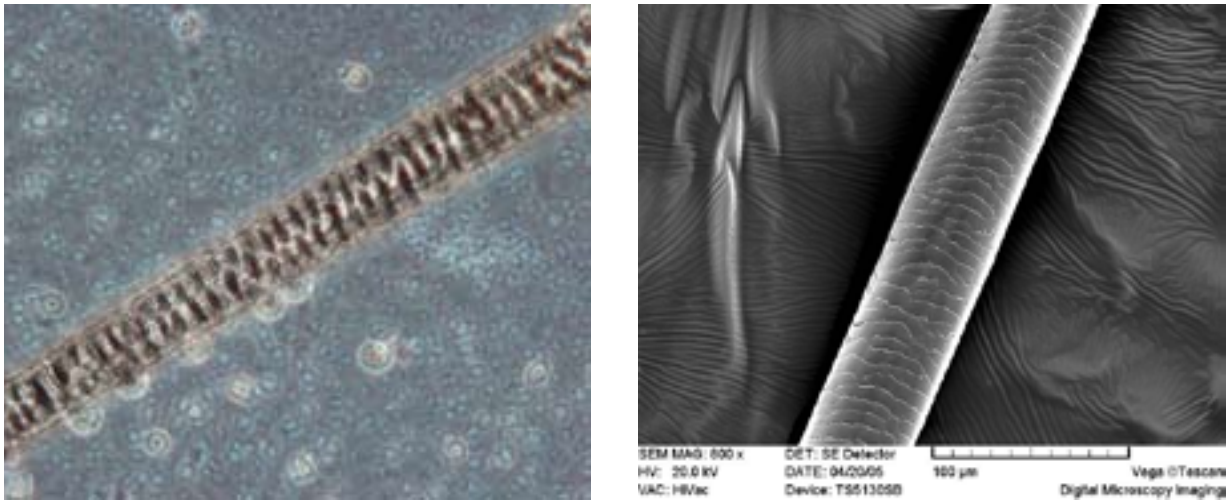

Figure 126. Medulla (left) and cuticula (right) of *Reithrodontomys megalotis.*

***Reithrodontomys montanus* - Plain Harvest Mouse** (SHM 131)

Medulla discontinuous, compound, flattened, 2 columns, rows formed but not fused, edges show pattern of scales. Cuticula imbricate, elongate, scales smooth, rows have mixed V- and W-pattern. Midshaft dia. 41µm.

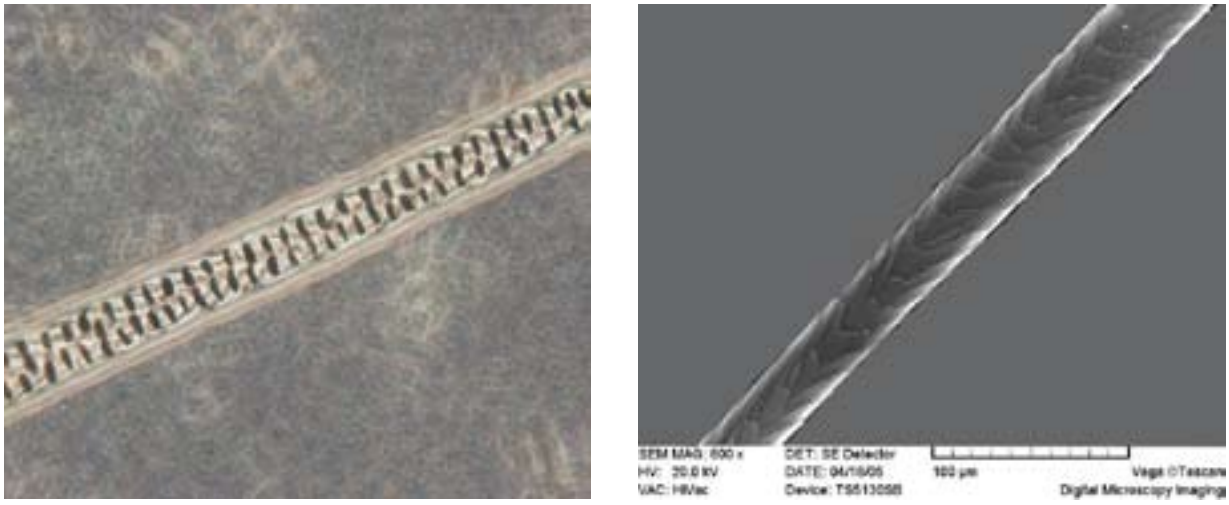

Figure 127. Medulla (left) and cuticula (right) of *Reithrodontomys montanus.*

***Peromyscus attwateri* - Texas Mouse** (SHM 679)

Medulla discontinuous, simple type a, oval, and occupies entire shaft. Cuticula imbricate, crenate, scales not smooth, 1-2 scales/row. Midshaft dia. 29µm.

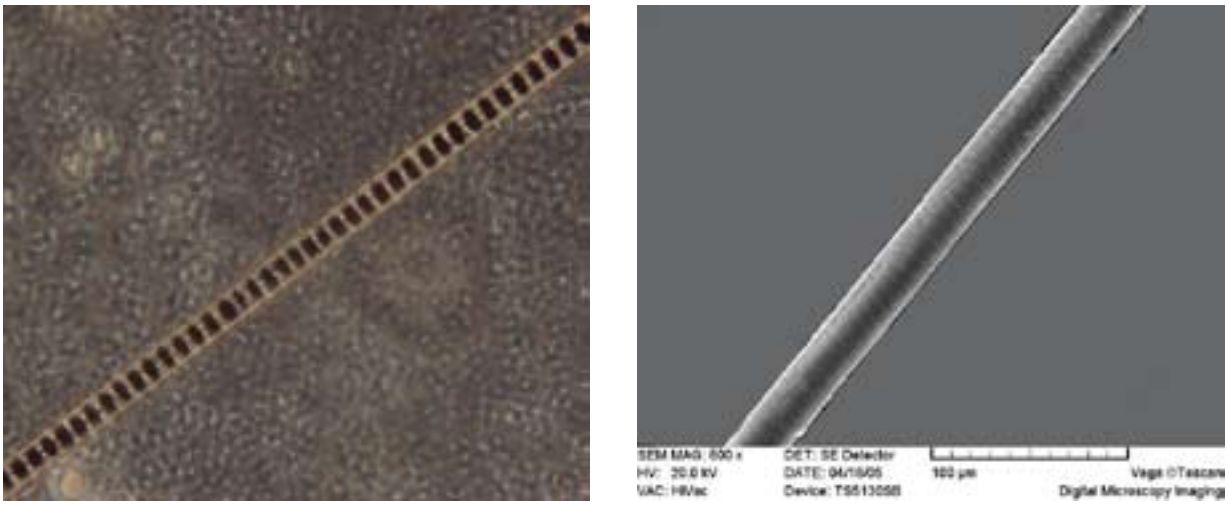

Figure 128. Medulla (left) and cuticula (right) of *Peromyscus attwateri.*

***Peromyscus boylii* - Brush Mouse** (TTU 75769)

Medulla discontinuous, compound, flattened, 3 columns, columns disrupted in some places, no rows formed, and occupies more than 1/2 of shaft. Cuticula imbricate, elongate with simple pattern. Midshaft dia. 17µm.

Figure 129. Medulla (left) and cuticula (right) of *Peromyscus boylii.*

***Peromyscus eremicus* - Cactus Mouse** (SHM 184)

Medulla discontinuous, compound, flattened, columns undefined, row fused with occasional interruptions in central area. Cuticula imbricate, ovate, mosaic, medulla visible. Midshaft dia. 25µm.

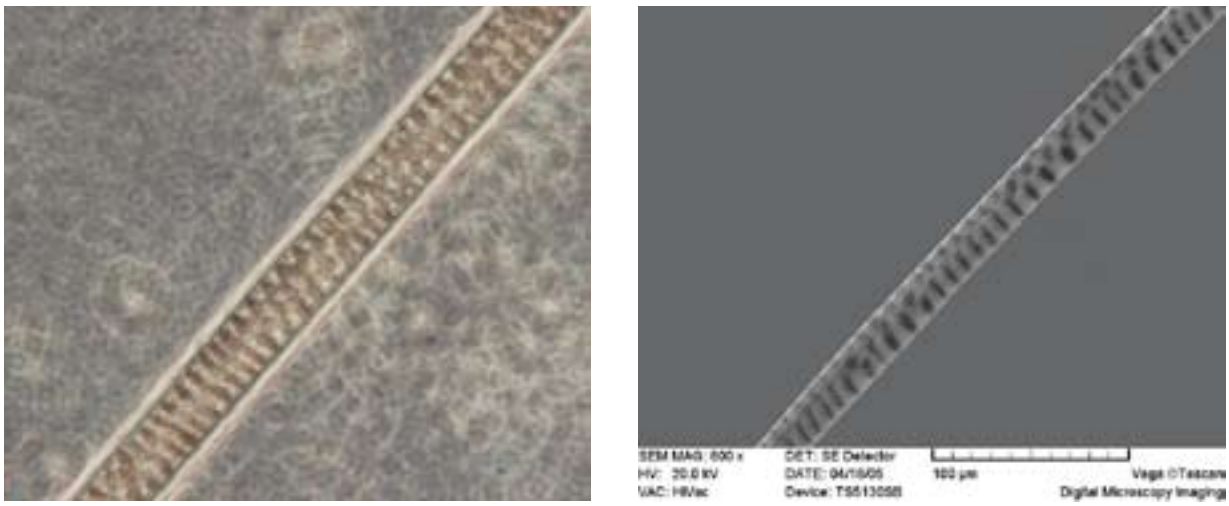

Figure 130. Medulla (left) and cuticula (right) of *Peromyscus eremicus.*

***Peromyscus gossypinus* - Cotton Mouse** (SHM 192)

Medulla discontinuous, compound, ovate, 2 columns, some rows fused, rough edges. Cuticula imbricate, crenate, smooth scales, 1-3 scales/row with some rows disturbed. Midshaft dia. 61µm.

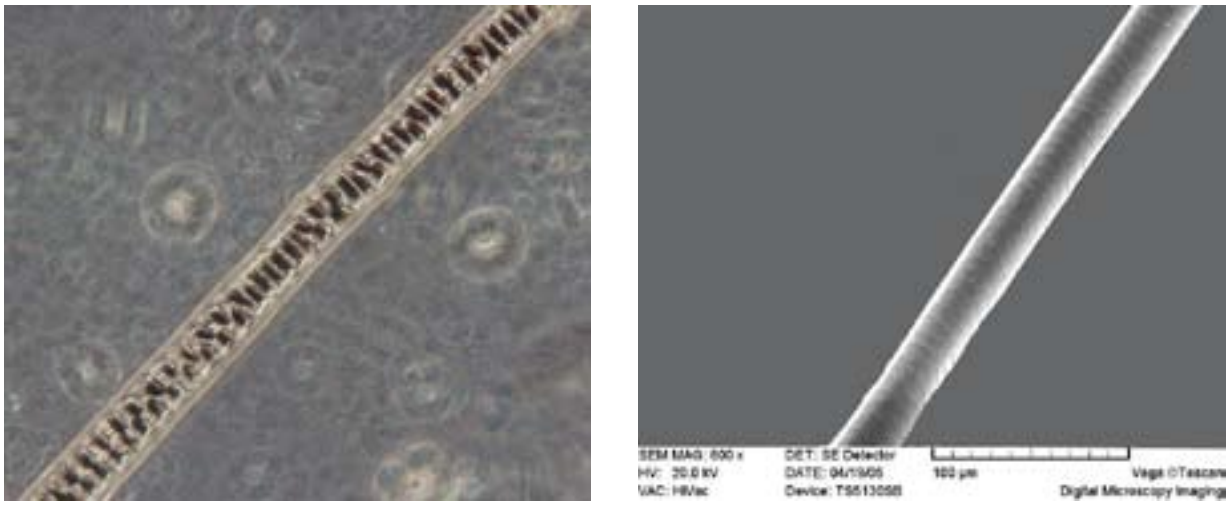

Figure 131. Medulla (left) and cuticula (right) of *Peromyscus gossypinus.*

***Peromyscus leucopus* - White-footed Mouse** (SHM 386)

Medulla discontinuous, compound, ovate, 2 columns, rows fused when formed but not numerous. Cuticula imbricate, crenate, scales not smooth, rows broken, 1-3 scales/row. Midshaft dia. 33µm.

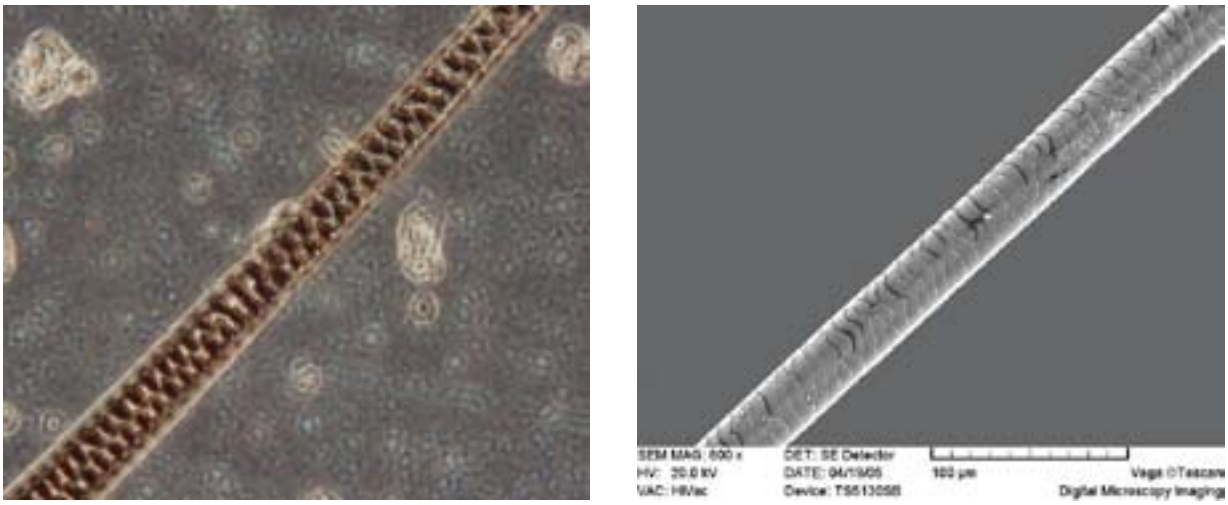

Figure 132. Medulla (left) and cuticula (right) of *Peromyscus leucopus.*

***Peromyscus maniculatus* - Deer Mouse** (SHM 281)

Medulla discontinuous, simple type a, rectangular "cells", and occupies entire shaft. Cuticula imbricate, crenate, scales not smooth, rows broken, 1-3 scales/row. Midshaft dia. 42µm.

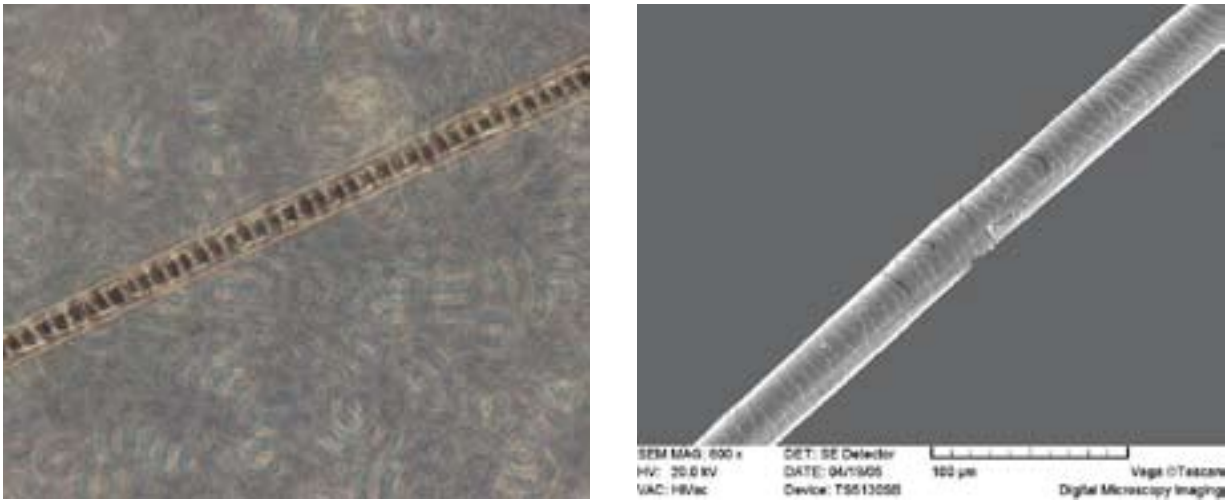

Figure 133. Medulla (left) and cuticula (right) of *Peromyscus maniculatus.*

***Peromyscus pectoralis* - White-ankled Mouse** (SHM 296)

Medulla discontinuous, compound, flattened, 2 columns, rows fused when formed but not numerous. Cuticula imbricate, crenate, scales smooth, 1-2 scales/row with some rows disturbed. Midshaft dia. 35µm.

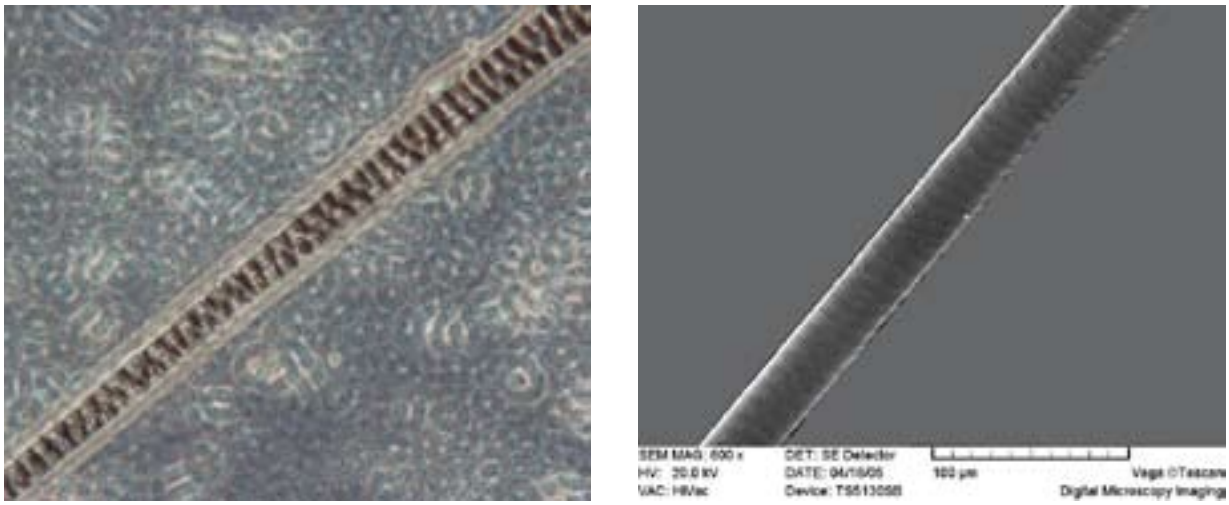

Figure 134. Medulla (left) and cuticula (right) of *Peromyscus pectoralis.*

***Peromyscus truei* - Pinyon Mouse** (SHM 618)

Medulla discontinuous, compound, flattened, 2 columns, most rows formed, no fused rows, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, wavy scales, rows disturbed, 1-2 scales/row. Midshaft dia. 25µm.

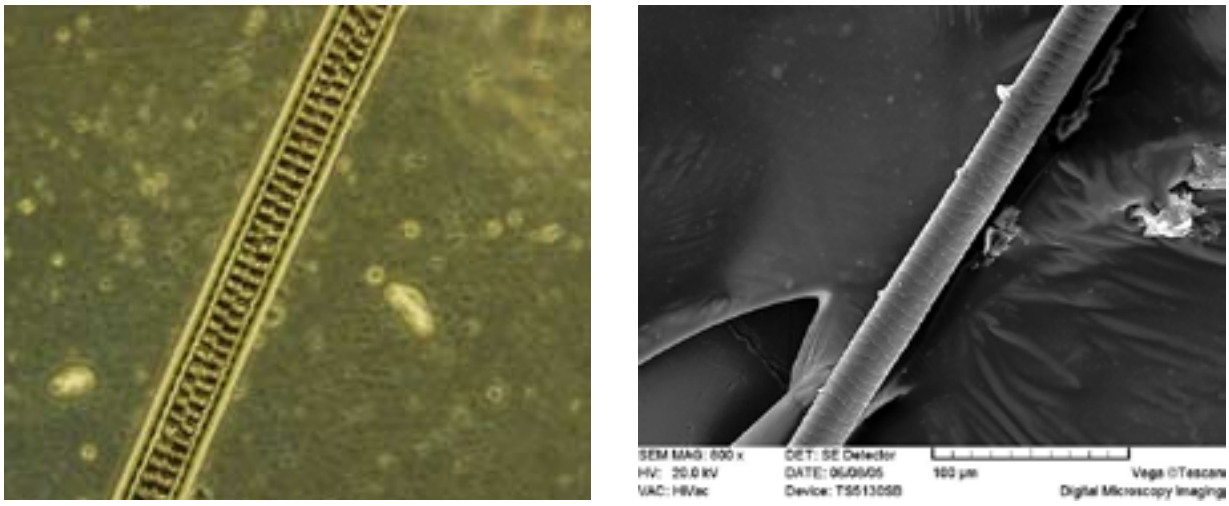

Figure 135. Medulla (left) and cuticula (right) of *Peromyscus truei*.

***Ochrotomys nuttalli* - Golden Mouse** (SHM 189)

Medulla discontinuous, simple type c, very flattened, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, smooth scales, 12 scales/row, not all rows parallel. Midshaft dia. 43µm.

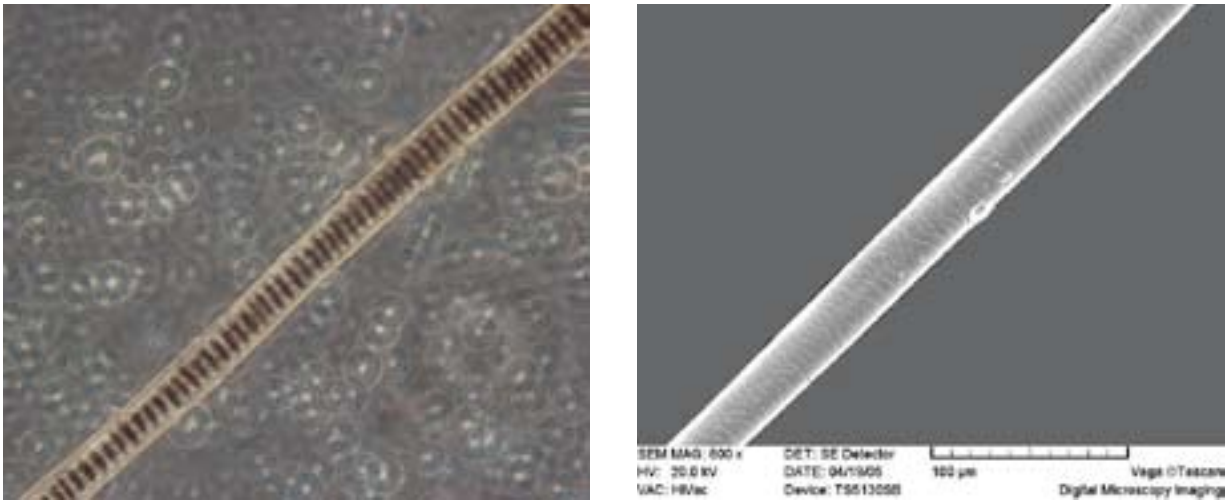

Figure 136. Medulla (left) and cuticula (right) of *Ochrotomys nuttalli.*

***Baiomys taylori* - Northern Pygmy Mouse** (SHM 143)

Medulla discontinuous, compound, flattened, 2 columns, some rows fused, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, smooth scales, some rows disturbed. Midshaft dia. 43µm.

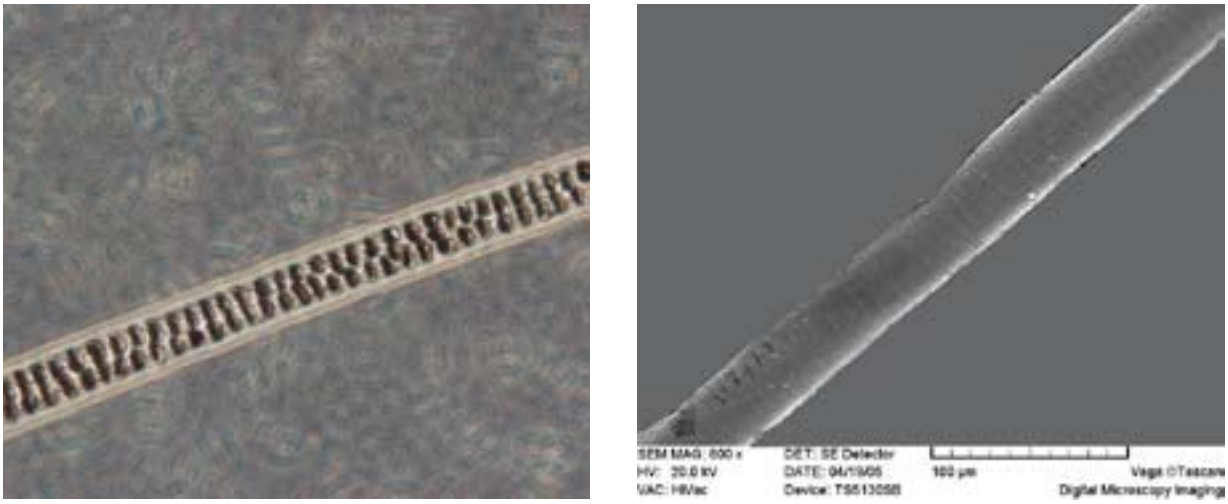

Figure 137. Medulla (left) and cuticula (right) of *Baiomys taylori.*

***Onychomys arenicola* - Mearns' Grasshopper Mouse** (ASNHC 10185)

Medulla discontinuous, compound, flattened, 2 columns, some rows fused, and occupies more than 1/2 of shaft. Cuticula imbricate, elongate, pattern simple. Midshaft dia. 8µm.

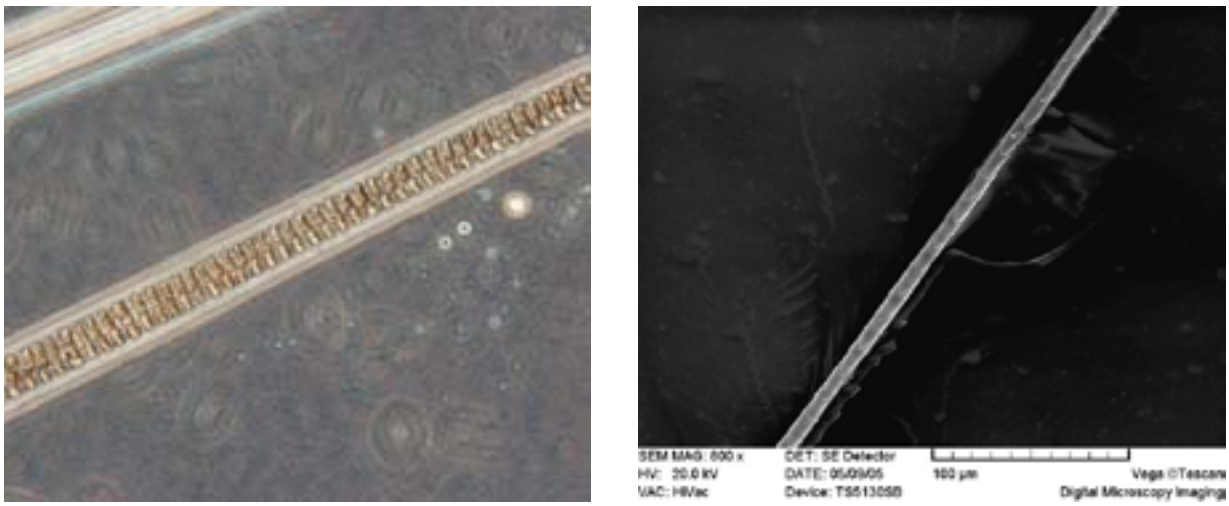

Figure 138. Medulla (left) and cuticula (right) of *Onychomys arenicola.*

***Onychomys leucogaster* - Northern Grasshopper Mouse** (SHM 976)

Medulla discontinuous, simple type a, square, and occupies entire shaft. Cuticula imbricate, crenate, scales not smooth, parallel rows sometimes broken by U-pattern. Midshaft dia. 30µm.

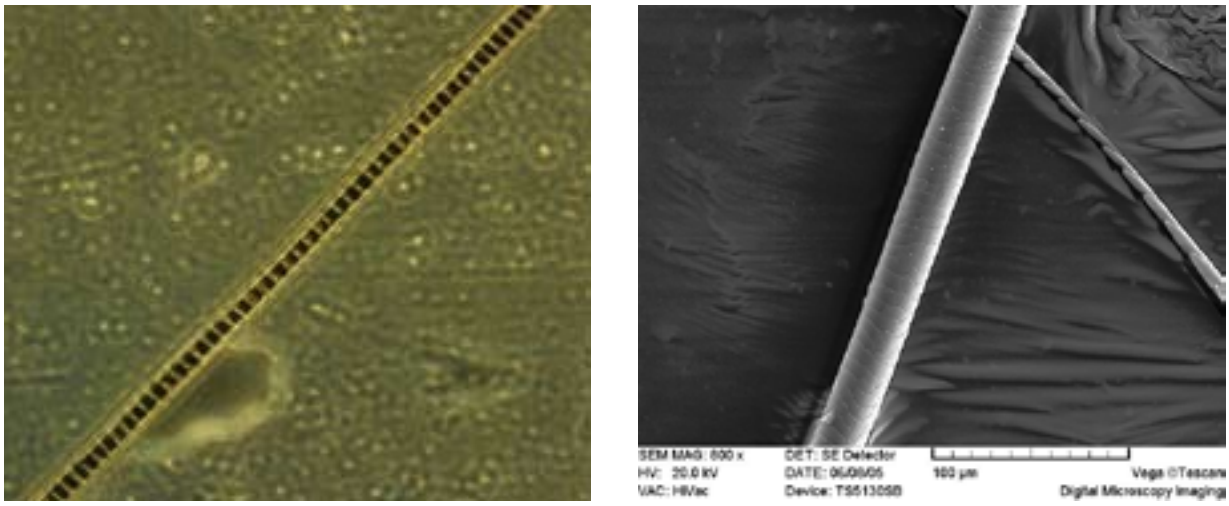

Figure 139. Medulla (left) and cuticula (right) of *Onychomys leucogaster.*

***Sigmodon fulviventer* - Tawny-bellied Cotton Rat** (ASNHC 7861)

Medulla discontinuous, compound, flattened, disturbed columns, rows mostly fused, and occupies entire shaft. Cuticula imbricate, crenate, flattened, with wavy scales and rows. Midshaft dia. 93µm.

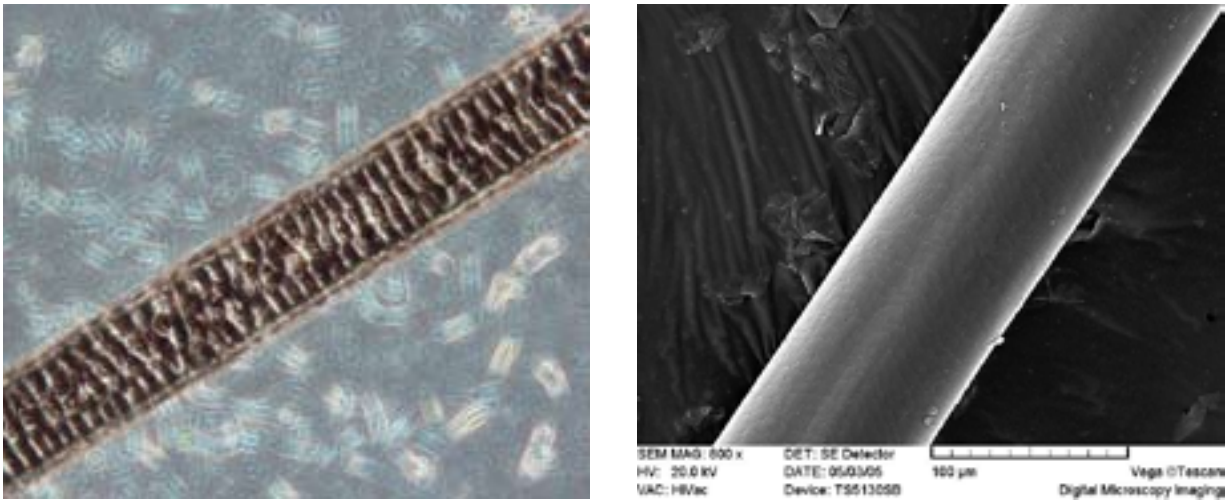

Figure 140. Medulla (left) and cuticula (right) of *Sigmodon fulviventer*.

***Sigmodon hispidus* - Hispid Cotton Rat** (SHM 77)

Medulla discontinuous, compound, flattened, columns disturbed, fused rows, and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, smooth scales, 1-2 scales/rows. Midshaft dia. 65µm.

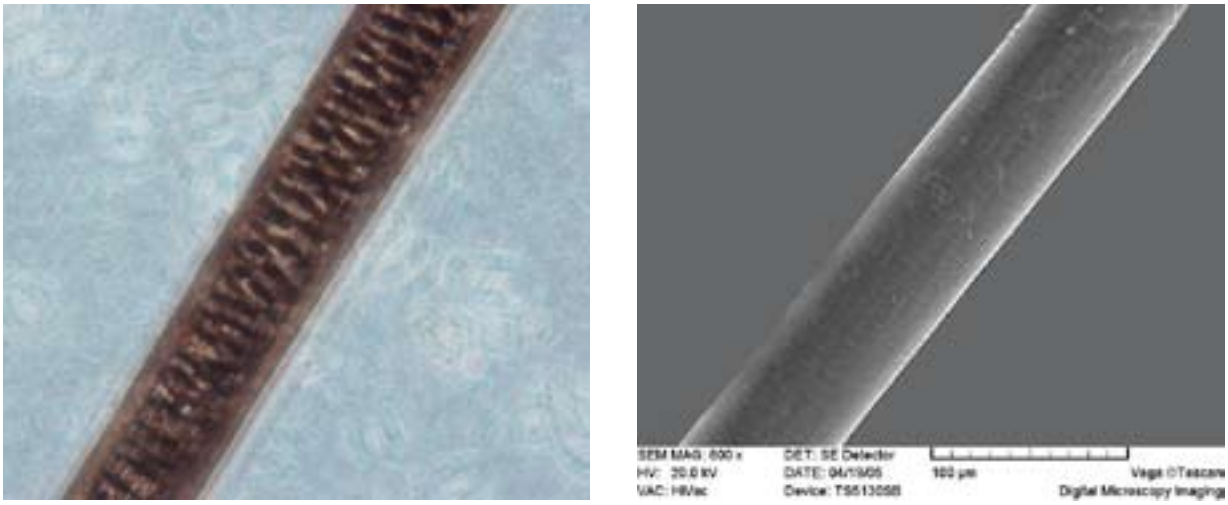

Figure 141. Medulla (left) and cuticula (right) of *Sigmodon hispidus.*

***Sigmodon ochrognathus* - Yellow-nosed Cotton Rat** (ASNHC 1083)

Medulla discontinuous, fragmental type c, cortical intrusions present throughout entire shaft. Cuticula imbricate, elongate, diamond pattern. Midshaft dia. 110µm.

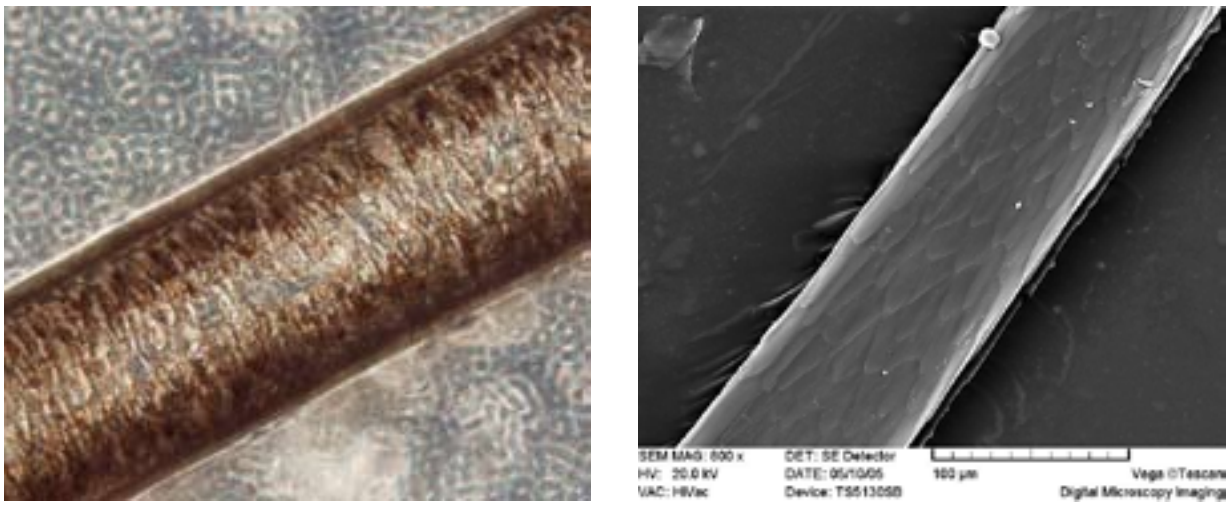

Figure 142. Medulla (left) and cuticula (right) of *Sigmodon ochrognathus*.

***Neotoma floridana* - Eastern Woodrat** (SHM 229)

Medulla discontinuous, compound, flattened, no columns, most rows fused, some rows disturbed. Cuticula imbricate, flattened, scales wavy and not smooth, rows parallel. Midshaft dia. 53µm.

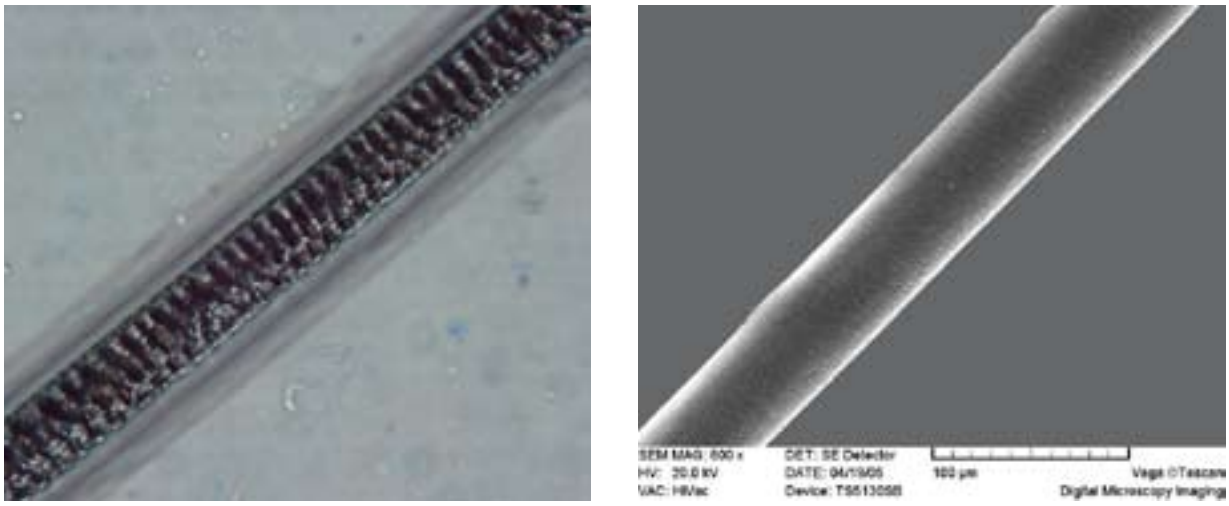

Figure 143. Medulla (left) and cuticula (right) of *Neotoma floridana.*

***Neotoma mexicana* - Mexican Woodrat** (ASNHC 569)

Medulla discontinuous, compound, mixed, single central column ovate, edge columns flattened, no rows. Cuticula imbricate, elongate, smooth scales, U-pattern, medulla very visible. Midshaft dia. 55µm.

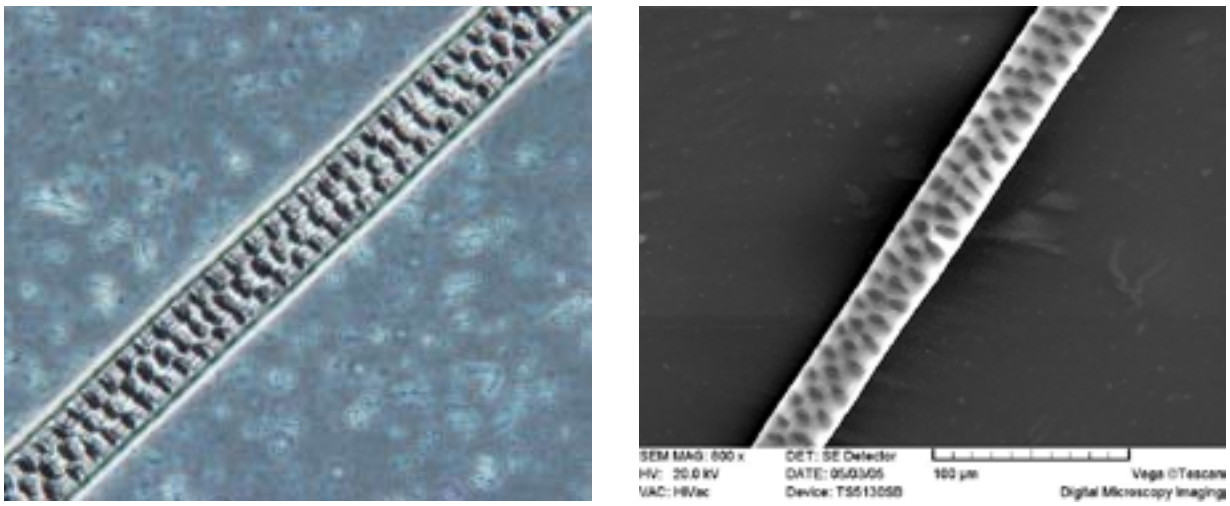

Figure 144. Medulla (left) and cuticula (right) of *Neotoma mexicana*.

***Neotoma micropus* - Southern Plains Woodrat** (SHM 58)

Medulla discontinuous, compound, flattened, 2-3 columns, no rows. Cuticula imbricate, crenate, smooth scales, 1-2 scales/row. Midshaft dia. 32µm.

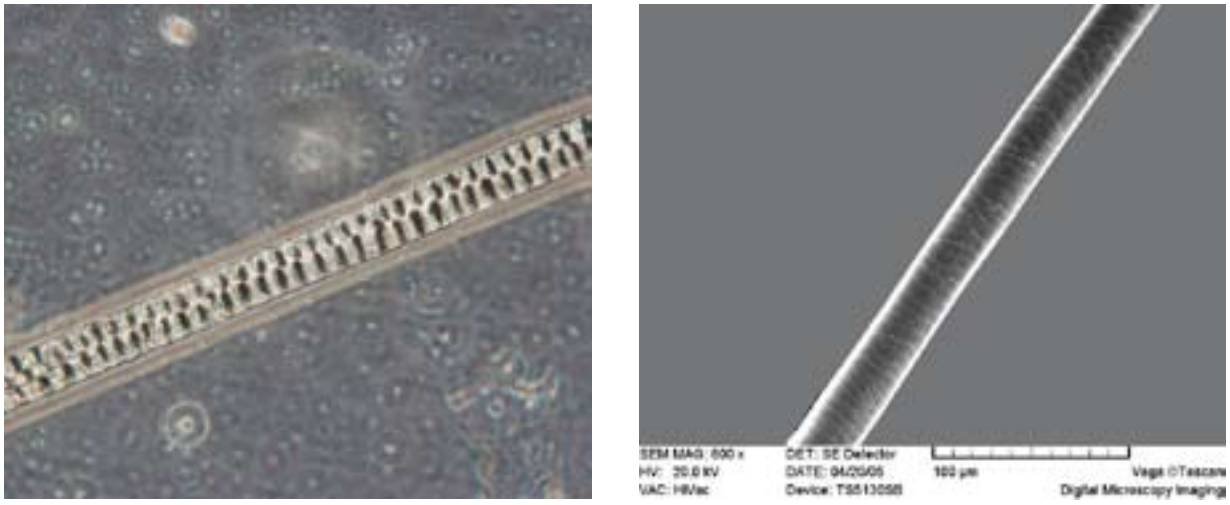

Figure 145. Medulla (left) and cuticula (right) of *Neotoma micropus.*

***Microtus mexicanus* - Mexican Vole** (ASNHC 1178)

Medulla discontinuous, compound, flattened, 5 columns, some rows formed, and occupies entire shaft. Cuticula imbricate, crenate, wavy scales, 1-2 scales/row, and rows parallel. Midshaft dia. 64µm.

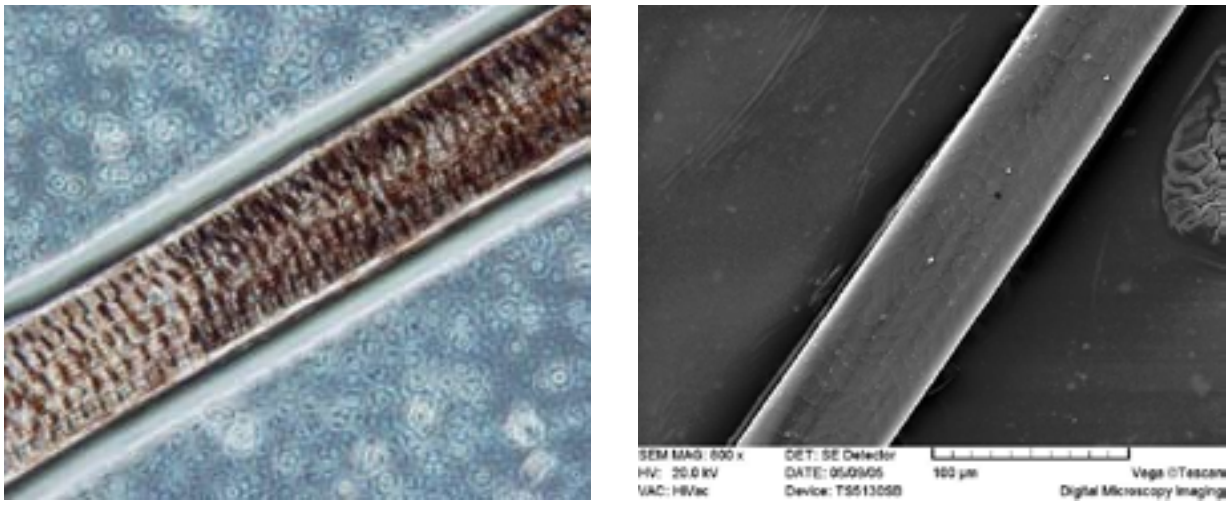

Figure 146. Medulla (left) and cuticula (right) of *Microtus mexicanus*.

***Microtus ochrogaster* - Prairie Vole** (SHM 385)

Medulla discontinuous, compound, mixed, 4 columns, no rows, central columns ovate, edge columns flattened. Cuticula imbricate, crenate, smooth scales, 1-3 scales/row, and rows indented. Midshaft dia. 96µm.

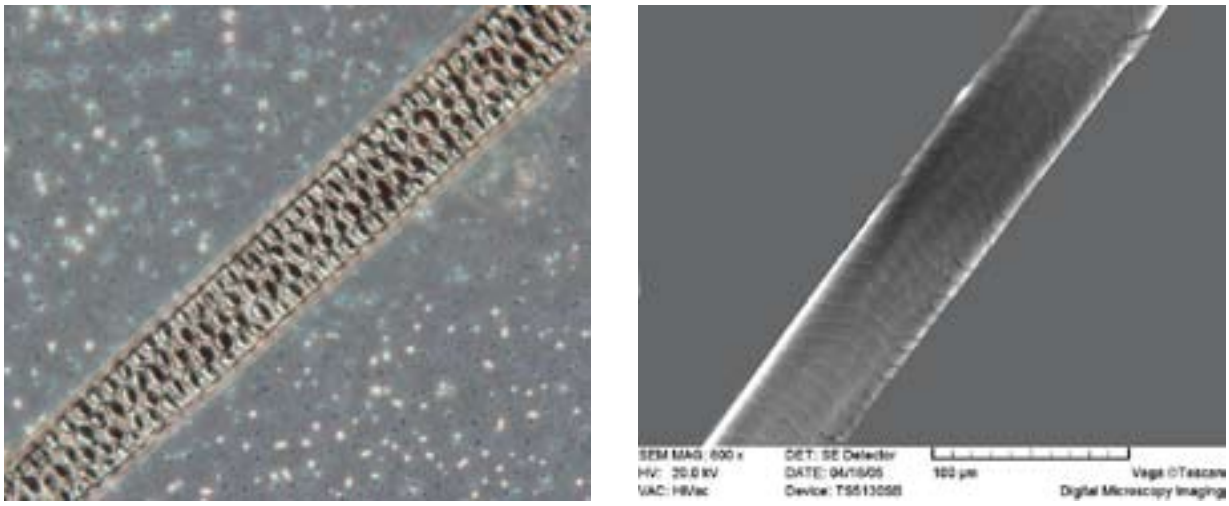

Figure 147. Medulla (left) and cuticula (right) of *Microtus ochrogaster*.

***Microtus pinetorum* - Woodland Vole** (SHM 130)

Medulla discontinuous, compound, flattened, 4 columns, some rows formed, and occupies entire shaft. Cuticula imbricate, elongate, smooth scales, mixed V- and W-patterns. Midshaft dia. 40µm.

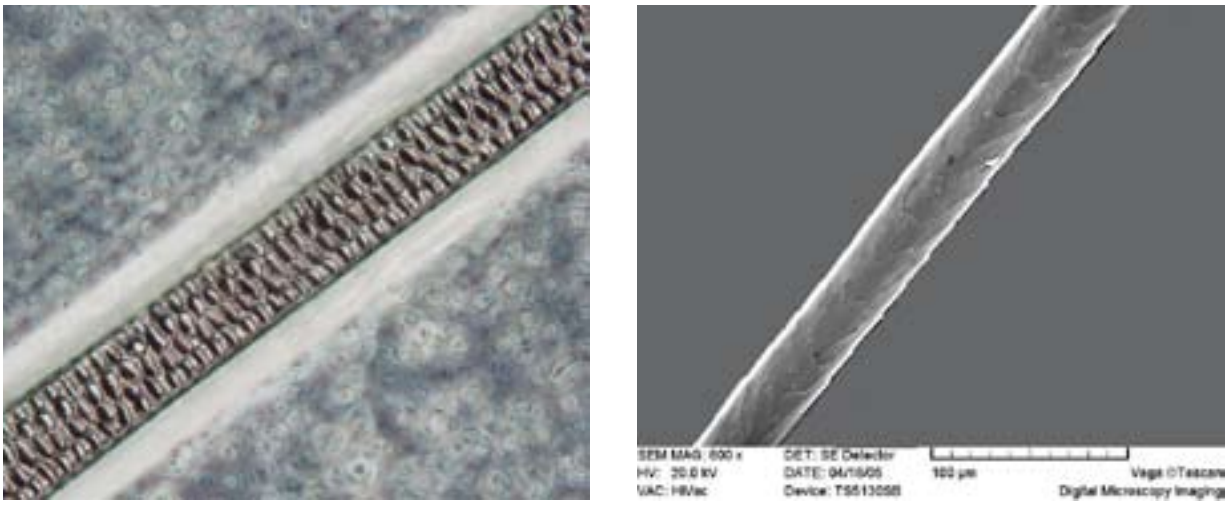

Figure 148. Medulla (left) and cuticula (right) of *Microtus pinetorum*.

***Ondatra zibethicus* - Muskrat** (TTU 92623)

Medulla discontinuous, compound, ovate, no columns, most rows fused, and occupies 1/2 of shaft. Cuticula imbricate, crenate, smooth scales with mosaic arrangement. Midshaft dia. 90µm.

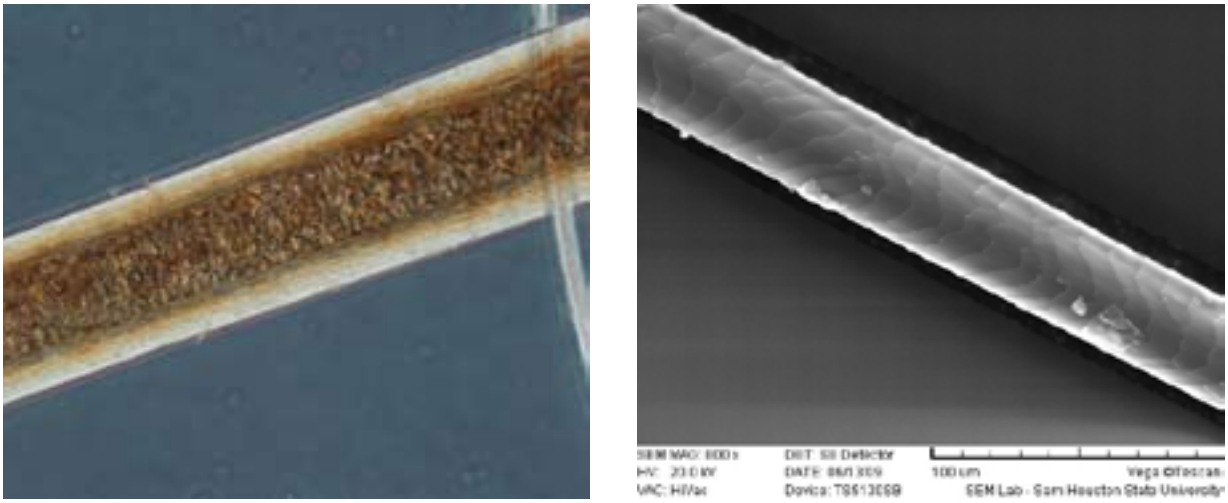

Figure 149. Medulla (left) and cuticula (right) of *Ondatra zibethicus*.

Family Muridae

***Rattus norvegicus* - *Norway Rat** (SHM 117)

Medulla discontinuous, fragmental type c, cortical intrusions only absent in central area. Cuticula imbricate, acuminate, smooth scales. Midshaft dia. 216µm.

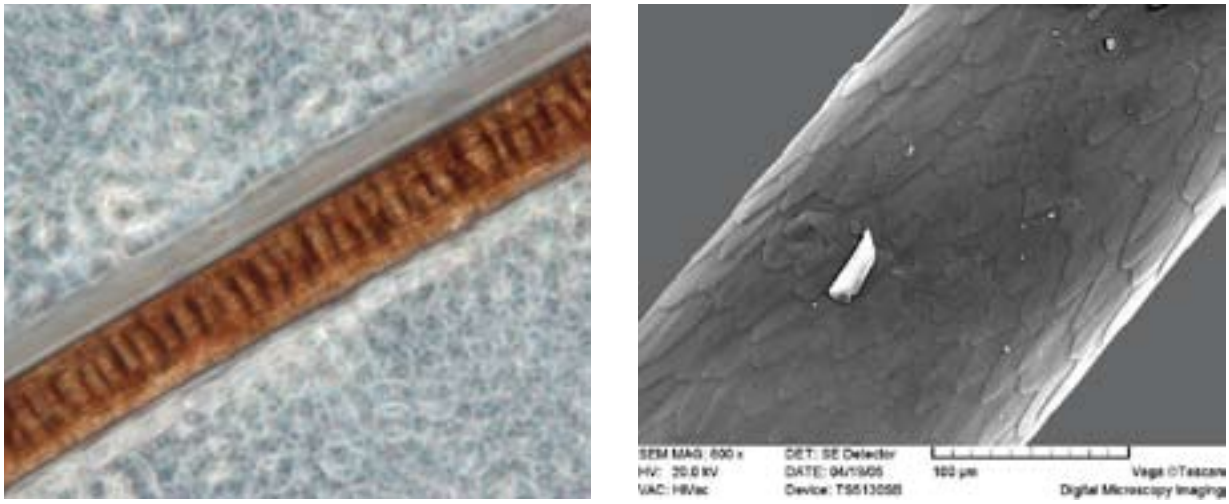

Figure 150. Medulla (left) and cuticula (right) of *Rattus norvegicus*.

***Rattus rattus* - *Roof Rat** (SHM 272)

Medulla discontinuous, fragmental type c, cortical intrusions cover entire shaft. Cuticula imbricate, acuminate, forms W-pattern. Midshaft dia. 134µm.

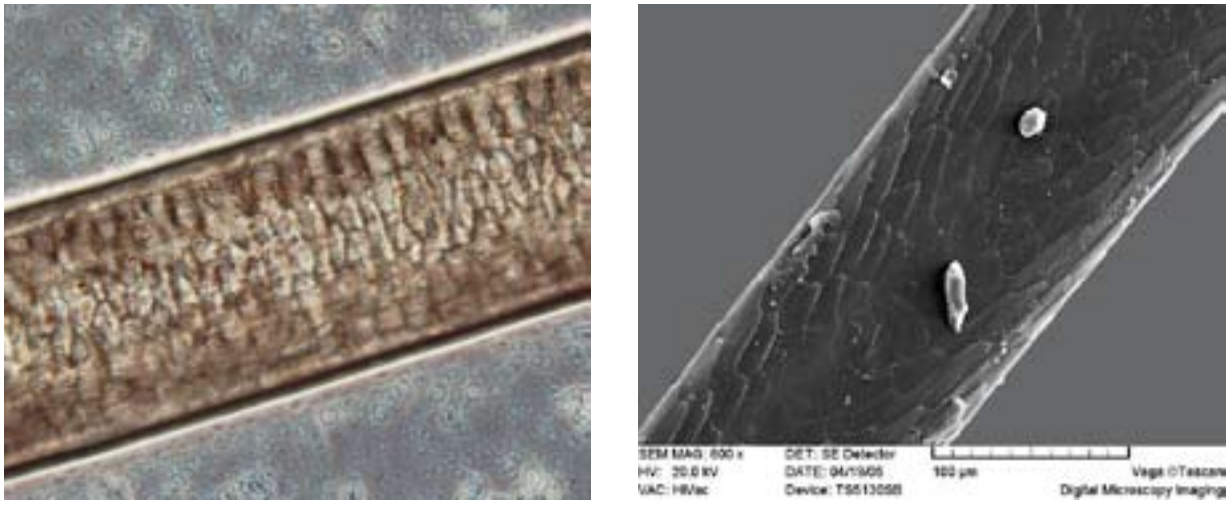

Figure 151. Medulla (left) and cuticula (right) of *Rattus rattus*.

***Mus musculus* - *House Mouse** (SHM 124)

Medulla discontinuous, compound, flattened, no columns formed, cortical intrusions present on edges. Cuticula imbricate, ovate, smooth scales, mosaic. Midshaft dia. 45µm.

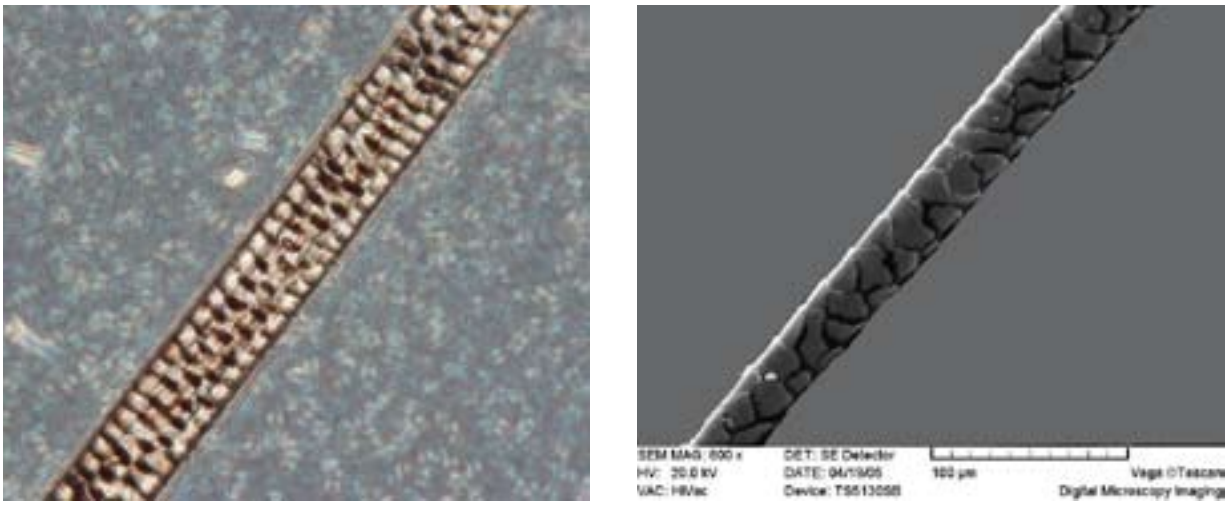

Figure 152. Medulla (left) and cuticula (right) of *Mus musculus*.

Family Erethizontidae

***Erethizon dorsatum* - North American Porcupine** (SHM 207)

Medulla discontinuous, fragmental type b, extensive cortical intrusions and occupies more than 1/2 of shaft. Cuticula imbricate, crenate, smooth scales and broken rows. Midshaft dia. 152µm.

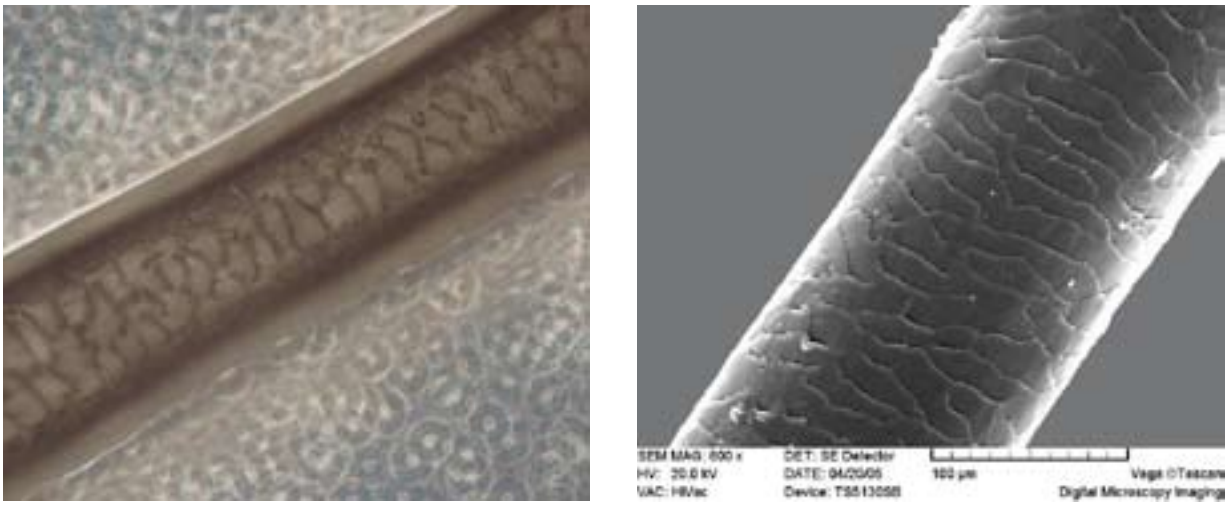

Figure 153. Medulla (left) and cuticula (right) of *Erethizon dorsatum*.

Family Myocastoridae

***Myocastor coypus* - *Nutria** (SHM 329)

Medulla continuous, nodose type a, flattened "cells", some appearance of rows. Cuticula imbricate, flattened, wavy and irregular scales and rows. Midshaft dia. 130µm.

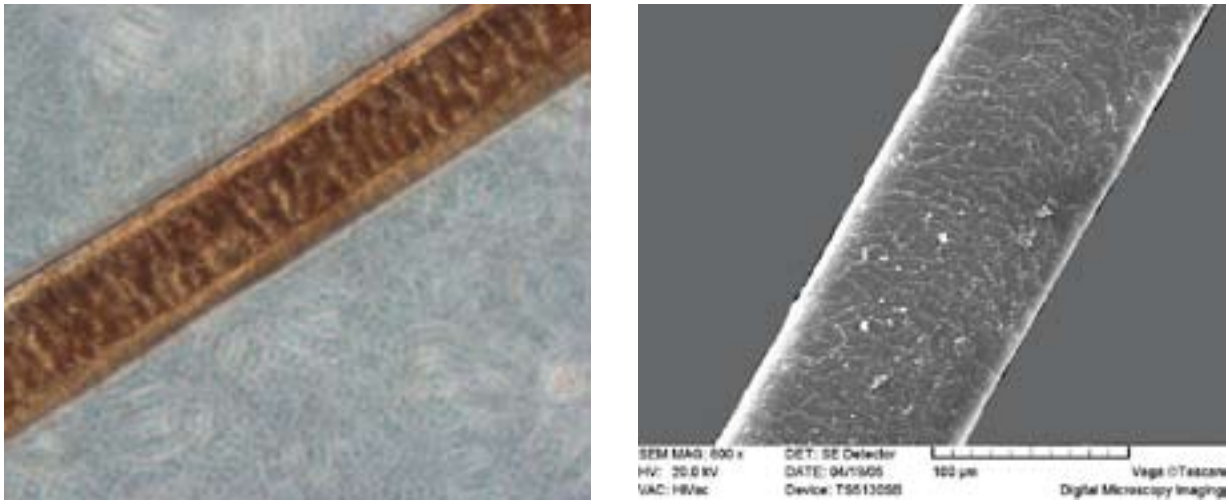

Figure 154. Medulla (left) and cuticula (right) of *Myocastor coypus*.

ORDER LAGOMORPHA - HARES AND RABBITS

Medulla continuous, nodose type b (Fig. 5b), "cells," ordered in columns.

1. "Cells" ordered in 3 straight columns.....*Lepus californicus* (Fig. 159)
   "Cells" ordered in more than 3 columns.....2

2. "Cells" ordered in 4-6 columns.....3
   "Cells" ordered in more than 8 columns.....4

3. Columns rounded, not entire shaft.....*Sylvilagus audobonii* (Fig. 156)
   Columns not rounded, entire shaft.....*Sylvilagus floridanus* (Fig. 157)

4. Cuticula flattened (Fig. 7e), no V-pattern.....*Sylvilagus aquaticus* (Fig. 155)
   Cuticula flattened (Fig. 7e), deep V-pattern.....*Sylvilagus robustus* (Fig. 158)

Family Leporidae

***Sylvilagus aquaticus* - Swamp Rabbit** (SHM 159)

Medulla continuous, nodose type b, ordered, more than 8 rows. Cuticula imbricate, flattened, smooth scales with parallel rows. Midshaft dia. 158µm.

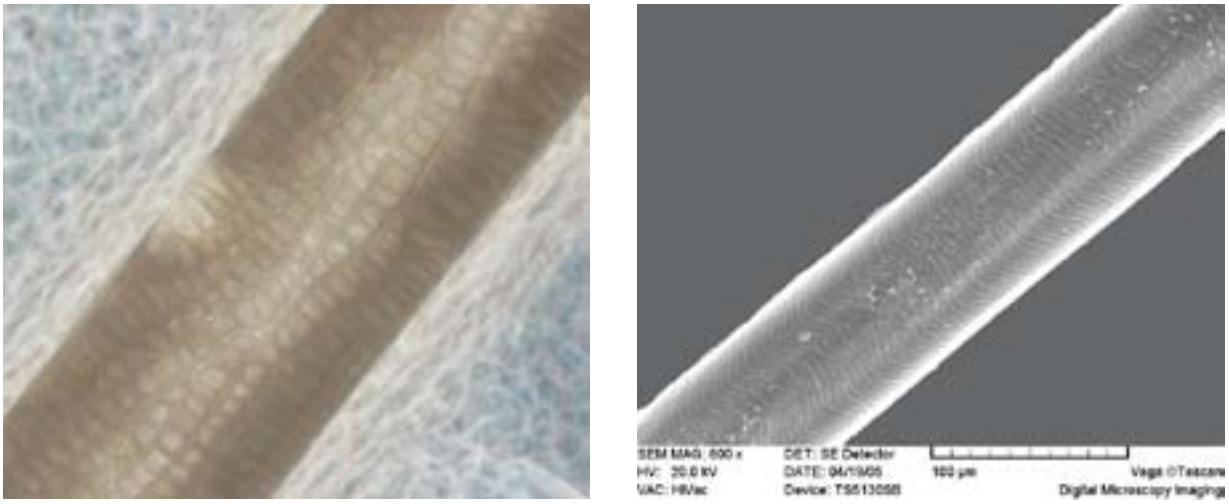

Figure 155. Medulla (left) and cuticula (right) of *Sylvilagus aquaticus*.

***Sylvilagus audobonii* - Desert Cottontail** (ASNHC 630)

Medulla continuous, nodose type b, ordered, less than 6 rows, and occupies more than 1/2 of shaft. Cuticula imbricate, flattened, scales hardly visible, and medulla is visible. Midshaft dia. 112µm.

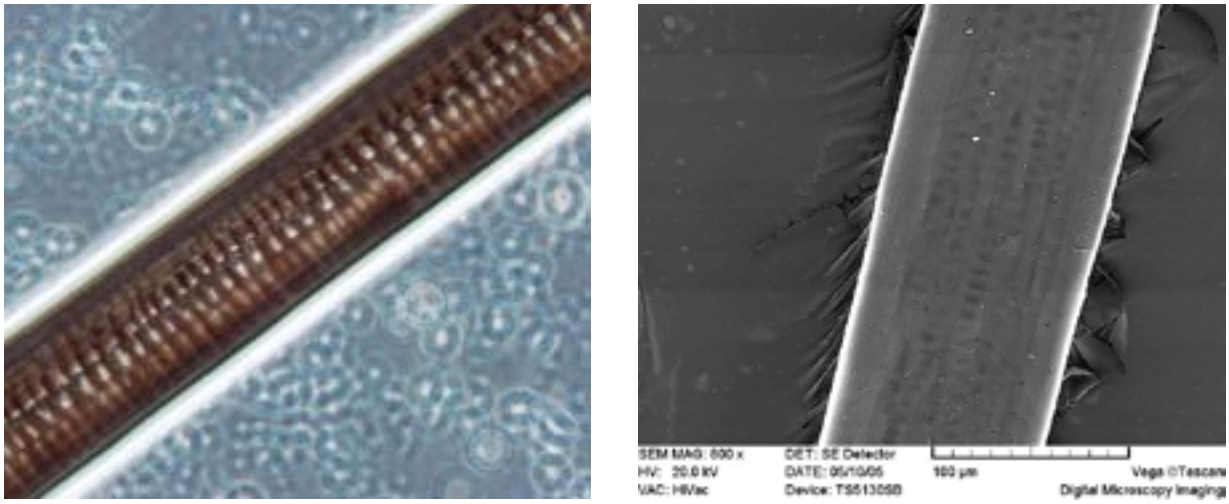

Figure 156. Medulla (left) and cuticula (right) of *Sylvilagus audobonii*.

***Sylvilagus floridanus* - Eastern Cottontail** (SHM 508)

Medulla continuous, nodose type b, ordered, less than 6 rows, and occupies entire shaft. Cuticula imbricate, flattened, scales wavy and hardly visible. Midshaft dia. 187µm.

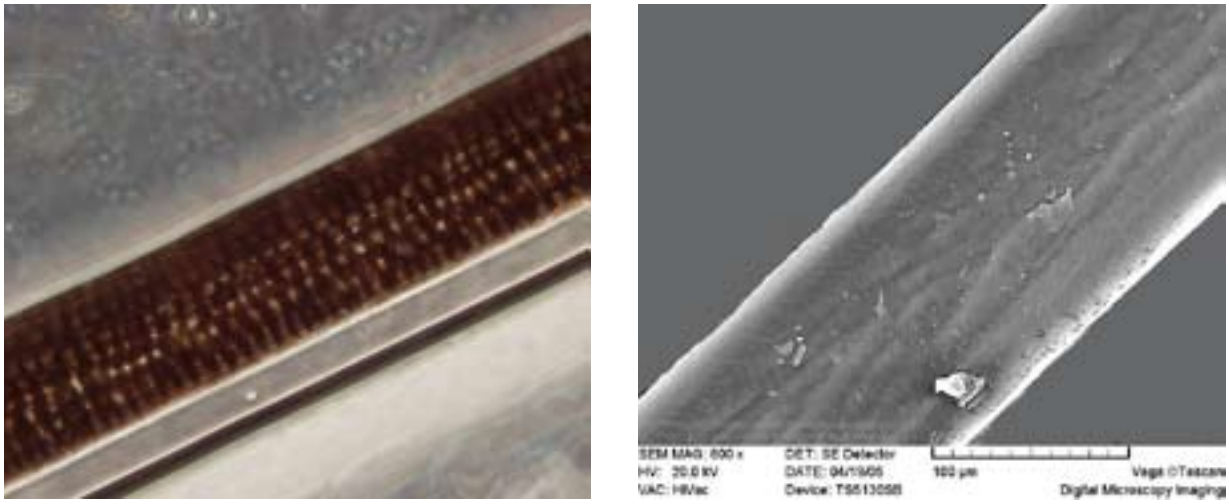

Figure 157. Medulla (left) and cuticula (right) of *Sylvilagus floridanus*.

***Sylvilagus robustus* - Davis Mountains Cottontail** (ASNHC 1138)

Medulla continuous, nodose type b, ordered, more than 8 rows. Cuticula imbricate, flattened, forms deep V-pattern with rows almost vertical. Midshaft dia. 112µm.

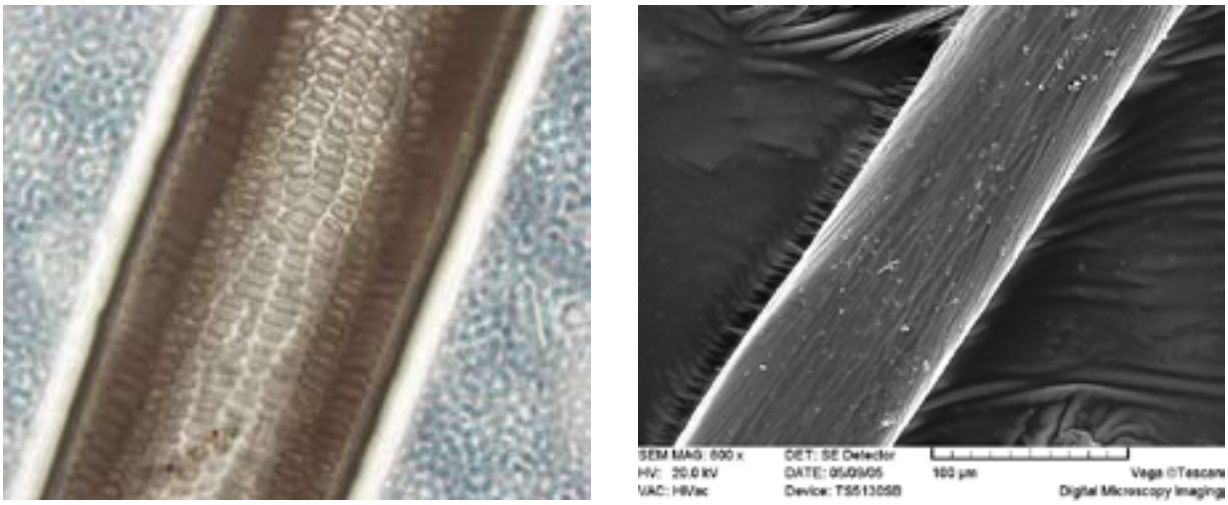

Figure 158. Medulla (left) and cuticula (right) of *Sylvilagus robustus*.

***Lepus californicus* - Black-tailed Jackrabbit** (SHM 38)

Medulla continuous, nodose type b, ordered, with less than 4 rows. Cuticula imbricate, crenate, smooth scales, with rows forming mixed V- and W-pattern. Midshaft dia. 116µm.

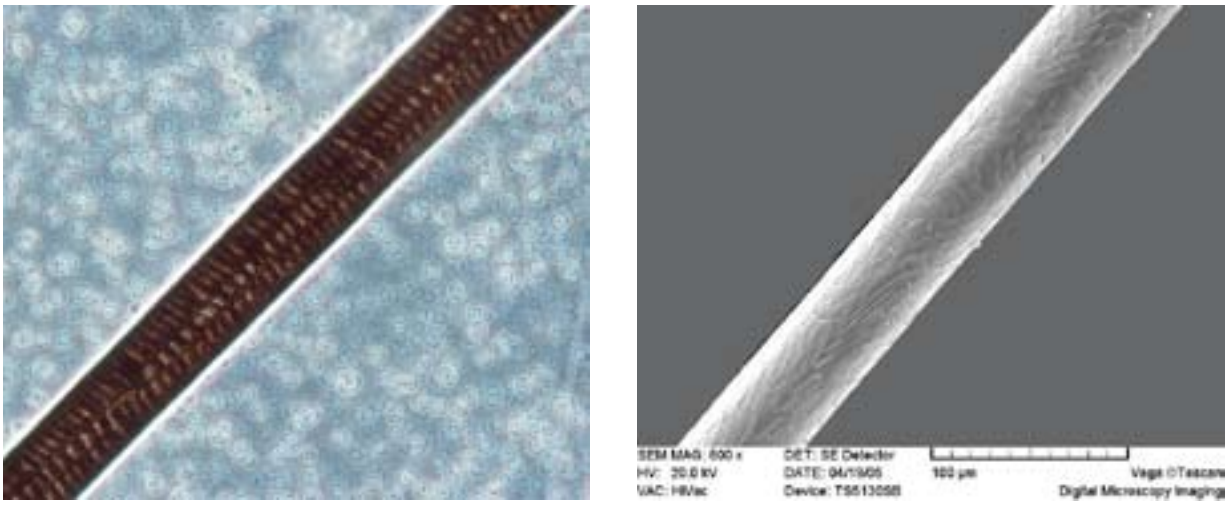

Figure 159. Medulla (left) and cuticula (right) of *Lepus californicus*.

ORDER PRIMATES – MAN

Medulla continuous, fragmental type a (Fig. 4a), and in some places absent.
Cuticula imbricate, crenate (Fig. 7d), with fully formed rows.....*Homo sapiens* (Fig. 160)

Family Hominidae

***Homo sapiens* – Humans** (A. Debelica)

Medulla discontinuous, fragmental type a, completely absent in some places. Cuticula imbricate, crenate, with rows not fully formed. Midshaft dia. 37µm.

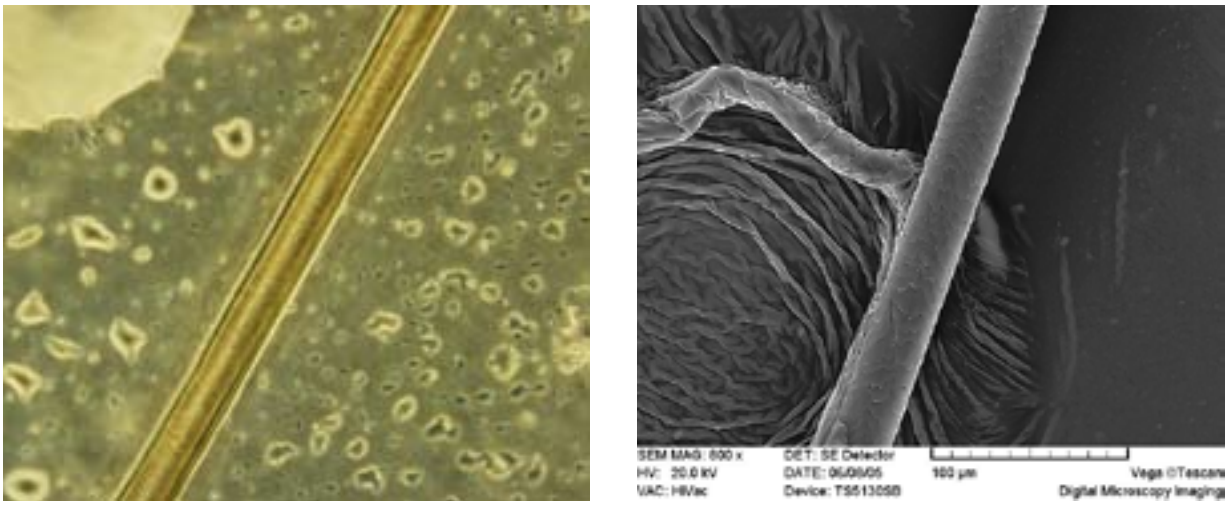

Figure 160. Medulla (left) and cuticula (right) of *Homo sapiens*.

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