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A KEY TO THE HAIRS
OF THE MAMMALS
OF SOUTHERN MICHIGAN

by
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TABLE OF CONTENTS

Introduction	1
Hair Structure	4
Hair Types	7
Tactile hairs	7
Guard hairs	8
Fur hairs	8
Intermediate hairs	9
Technique	10
Cross-sectioning	11
Scale examination	13
Key	15
Division I	17
Division II	21
Literature Cited	29
Illustrations	30
Appendix	39

INTRODUCTION

Hair, universal to almost all mammals, occupies an important place in biological studies. Food habits research involving fecal and pellet analysis probably best illustrate the use to which a knowledge of hairs can be put in wildlife management. Hairs are, of course, found under many different circumstances. A cluster of hairs may be the only clew evident where a case of predation has taken place or various types of accident may have occurred. Other conditions under which hairs may be found include hairs left in sprung traps or dislodged at the entrances to caves or dens. The authenticity of fur garments is often questioned, but this wider problem is not considered in this discussion.

There is a paucity of information which is sufficiently specific to enable a beginner to identify hairs of even the common mammals. The practice now prevailing is for a person not familiar with hairs to identify an unknown sample by the laborious, hit-or-miss process of comparing the unknown with a known sample. It is hoped that this key will make it possible for the beginner to identify many hairs without resorting to the comparison method. After observing specific characters mentioned in the key, it probably will also be possible

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1. The writer has studied only the hairs of the mammals mentioned in the key. Generalizations are mostly concerned with this limited group of mammals and can hardly be expected to be true in all cases for areas with a different fauna.

to recognize certain hairs without the use of the key.

Only the hairs of the mammals of southern Michigan (south of township line 16) are treated in this key. A few mammals rarely found on this area have been omitted. Distinguishing criteria given in the key are not necessarily valid for related species of even adjoining areas although it is anticipated that the key may be of some value for identifying hairs of mammals not found on the area considered in this paper. Domestic as well as the wild mammals have been included in the key although they have been described only sufficiently to distinguish their hairs from those of the wild mammals. Some species have been grouped together even though their hairs are probably distinct enough to permit identification down to species especially if the fur hairs were studied in more detail. Others have been grouped because of the close resemblance between their hairs.

There may be three or more types of hairs existing in considerable numbers on any individual mammal. The hairs within each type vary chiefly with the season of the year (prime-ness) and with the age of the mammal. Young mammals are at first provided with a fine, fluffy coat of hairs: The writer had no opportunity to study these hairs so that it is not known whether or not they can be identified by means of the key. However, at the age of several weeks, hairs characteristic of the adults appear which, although small at first, are similar in structure to hairs of the adults and do not merit special

consideration. Gunn (4,5) after intensive studies of the differences between prime and unprime pelts states, "the conclusion may be drawn that the differences represent merely different phases in the life cycle of the hair." Hadwen (6,7) in studying the color changes in snowshoe hares found that the whitening of the hairs was due to a blanching of the pigments of the hair shaft and not to the growth of an entirely new coat of white hairs. By clipping and dyeing some brown hairs, he was able to identify these same hairs after they had turned white. A degeneration of mature hairs, particularly noticeable in clipped hairs, was observed in the white snowshoe rabbits. These frayed hairs, which he called kempy fibers, are never present to the exclusion of the easily recognized sound hairs. Many other species of mammals have stronger hairs which are not likely to be thus destroyed.

Other writers, Allen (1) and Grange (3) contend that the whitening of the hairs is due to the growth of a new coat of white hairs. Whatever the case may be, the changes in a hair becoming prime, or white in the case of the variable mammals, is essentially a change in the pigmentation of the hair, the gross structure not being materially altered. But pigmentation has not been made a major feature of the key owing to a further reason, the diversity of pigment granule arrangement in the hairs of certain species. Pigments may be uniformly distributed throughout the cortex, concentrated in longitudinal bands, or lacking entirely. There is also much variation in the size

and color of the pigment granule itself. A third factor is the deterioration they sometimes undergo if subjected to weathering or to the action of digestive juices.

The hairs from the back, sides, and belly are usually similar in structure. The color pattern may be identical in these regions, or as is often the case, lighter or differently colored on the ventral surface. Undoubtedly most hair analyses will be concerned with body hairs inasmuch as they constitute such a large percentage of the total numbers of hairs. Head, leg, and tail hairs may be of the same or of totally different structure. Head hairs of average size are sometimes considerably flattened and of greater diameter than any of the body hairs.

HAIR STRUCTURE

Description and classification of the variations in hair structure and form are taken with certain modifications from the data provided by Dr. L. A. Hausman. (9,10,11). The parts of a hair are the root, the bulbous portion situated beneath the surface of the skin, and the shaft, the portion extending above the surface. The shaft of a typical hair is composed of three elements, the medulla, cortex, and cuticle (Figs. 1,2). The medulla is a central core or pith composed of shrunken cells of irregular shape, air chambers, and pigments. Three types of medullae are referred to in the key. The discontinuous medulla is one in which isolated individual chambers can be seen, and the chambers lie in a single row. This type of

medulla is most commonly found in fur hairs and may occupy a large proportion of the shaft (cortex relatively thin as seen in Fig. 3) or a smaller percentage of the shaft (cortex relatively thick as seen in Fig. 4). Masses of melanin or pigment granules dispersed between the medullary chambers may cause the medulla to appear continuous at first glance (Fig. 4).

The continuous medulla is characteristic of guard hairs although it is found in other types of hairs also. A few variations of the continuous medulla are shown in Figs. 5-7. Fig. 5 illustrates the outline of a nodose continuous medulla or one of irregular construction in contrast to the homogeneous medulla (Fig. 6) which has a more uniform, granular construction. The nodose medulla is well exemplified by the larger hairs of many rodents. The medulla is fragmental when it consists of unconnected fragments of varying length (Fig. 8). Hairs of some species commonly have a continuous medulla in part of the shaft and a fragmental medulla in the remainder. Or a continuous nodose medulla frequently becomes discontinuous for a short distance before it disappears at the tip of the hair.

Guard or intermediate hairs of the rodents may have a compound medulla which is most common in this order of mammals. This type of medulla is shown at different regions of a hair in Figs. 9 and 10. The nodose continuous medulla may be so pigmented as to produce basically the same effect of alternating masses of melanin. To convenience many future references to these types of medullae, they have been called the "rodent base".

The rodent base is usually seen in the basal portion of the hair, and its appearance varies with the character of the pigment granules in the cortex and medulla. After becoming familiar with the rodent base, it can be recognized in hairs with a heavily pigmented cortex or hairs in which the melanin of the medulla is lacking. The rodent base may also be seen in the guard hairs of rabbits. Only very rarely are the medullae of hairs in other groups of mammals so constructed as to produce the rodent base effect.

The cortex is a hyaline layer of fusiform cells surrounding the medulla. Its cells are transparent and partially fused together so that they cannot be readily seen unless treated with acids or alkalies. The cortex contains air spaces and pigments which are partially responsible for the characteristic colors of hairs. The pigments may be either in the cells themselves or in the spaces between the cells. Pigments are diffuse or in the form of granules, the latter being the more common of the two. Usually there is diffuse pigment associated with pigment granules but only to a minor extent (Boyd,2).

A single layer of flattened, transparent cells constitute the cuticle or outermost layer of the shaft. Cuticular scales fall into two groups, imbricate scales (Fig. 11) and coronal scales (Fig. 12). An ~~annulate~~ coronal scale extends completely around the shaft while a single imbricate scale extends only part way around the shaft with the base of each scale beneath the distal portion of the adjoining scale.

HAIR TYPES

Hairs can roughly be divided into four groups: specialized hairs, guard hairs, fur hairs, and hairs intermediate to guard and fur hairs. Many oddities in specialized hairs can be seen in certain mammals throughout the world. The quills of the porcupine found in northern Michigan are markedly dissimilar to any of the hairs of mammals of southern Michigan. Tactile hairs or whiskers, a form of specialized hair common to practically all mammals, are found on the head or sometimes on the forelegs. Tactile hairs can be told from all other types of hairs by the following characteristics: They are the only hairs which constantly decrease in diameter from the base to the tip of the hair. All other hairs, excluding hairs with nodes and internodes, taper toward both the base and the tip. The medulla is often lacking. When present, it is never a conspicuous element of the hair, but is much reduced in size. Typically it is continuous at the base, but soon becomes fragmental and disappears. These hairs are also characterized by an extremely long drawn-out tip which is not found in other hairs of corresponding size. Cross sections are circular or nearly so in all cases. Generally the cortex contains dark pigment granules which may be so numerous as to conceal the medulla. There is considerable range in the size of tactile hairs from any one individual, the largest hairs often being longer and larger in diameter than any of the body hairs. Large tactile hairs are made conspicuous by their size in pellets and feces

containing large quantities of hairs of the smaller mammals. Tactile hairs are readily recognized as such and, being very similar in structure between the different species, they are of no value for identification purposes. Therefore these hairs have not been included in the key or taken into account in the following discussion.

Guard Hairs. The largest hairs in diameter and length are the guard or protective hairs. The medulla of guard hairs is generally continuous. A typical form of guard hair is one which is fusiform in shape or of largest diameter near the mid-region and tapers toward both ends of the hair. Cross sections of guard hairs may assume a variety of shapes never found in fur hairs. The scales are often closely appressed for the entire length of guard hairs, giving them a high luster. Short guard hairs may exhibit very much taper while long guard hairs sometimes show very little taper.

Fur Hairs. Fur hairs are the finest hairs of a pelt and constitute what is known as the underfur. They often have a discontinuous medulla, prominent scales, and are never enlarged at their distal ends. Many fur hairs have nodes and internodes, an internode being a constriction of the shaft (Fig.13) while a node is that portion of the shaft lying between two internodes. Pigmentation, except at the tip of the hair, is generally confined to the medulla, with a lesser number of species having pigments in the cortex of the hairs. Except at internodes and the extremities, fur hairs have very little

taper, the edges appearing parallel under the microscope.

Intermediate Hairs. These are the intergrades between fur and guard hairs. A common type is one enlarged in the distal portion while the basal part is finer and similar to fur hairs in structure. These hairs have been called pile hairs in rabbits and rodents. Hair structure may or may not indicate taxonomic relationships. In some genera, such as Mustela, the hairs of the various species appear identical except in size. In other instances, hairs of widely unrelated species appear almost identical. Thus the long dark guard hairs of the brown rat appear very similar to some leg hairs of the skunk, excepting that the scales at the base of the hairs are transverse in the skunk and longitudinally disposed in the brown rat.

Size is of some value in hair identification. For each species there is a maximum diameter and length beyond which it is unlikely that larger hairs will be found. Thus given a hair of a certain length, the mammals never having hairs that long are eliminated from further consideration. For instance, a hair 40 mm. long belonging to the genus Mustela could not be referred to the least weasel because it never has hairs that long. However, a similar hair only 10 mm. long could have come from the back of a least weasel or the head or legs of a mink or New York weasel.

The key is based almost entirely on guard and intermediate hairs, for they are easier to handle and more characteristic

of the species. The coarser hairs are not injured as much as fur hairs by the action of digestive juices although even guard hairs may be broken by mechanical forces. Fur hairs, having a thinner cortex, are often found to be severely macerated and discolored in feces and pellets, the medulla frequently being totally blackened, Occasionally a sample of fur hairs is found without any guard hairs being present. In general, though, fur hairs are so fine that they probably escape notice unless if they are quite abundant in which case guard hairs are likely to be present also.

TECHNIQUE

Certain equipment is needed for the efficient microscopical examination of hairs. The microscope should be provided with an ocular micrometer, Abbe condenser, and a daylight lamp. A mechanical stage is almost a necessity for proper manipulation of the hair while under observation, for it is desirable that any portion of a hair can be brought into the microscopic field quickly and easily. Measurements of diameter in micra (one micron is equal to 1/1,000 of a millimeter) are taken with an ocular micrometer. Details as to the use of the microscope and its accessories can be found in any of the textbooks of micrology or microtechnique. Except when very dirty, hairs can be mounted directly in an essential oil (oil of cloves, oil of bergamot, etc.) or in xylene for longitudinal examination. These reagents clear or make the elements of the

hair more clearly visible under the microscope. Xylene is a good medium to use, for after the hairs have been examined, the slide and cover glass can be wiped clean with a dry cloth, thus eliminating the task of washing the slides. The room should be well ventilated, for xylene evaporates readily and has a penetrating, slightly disagreeable odor. Only transmitted light need be used in the examination of hairs and cross sections. Dirty hairs can be washed in a volatile, grease dissolving reagent such as alcohol, ether, or carbontetrachloride.

Cross-Sectioning Hairs. To successfully use the key, it is frequently imperative that the character of the cross sections be known, either at a stated region of the hair or serially along the entire length of the hair. The cross sections can be obtained by the method previously reported by the writer.*- The serial drawings of cross sections (Figs. 26-35) are shown as they appeared in individual hairs while the composite illustrations (Figs. 22-25) represent cross sections of a group of hairs. They are to show the general shape and proportions of the cortex and medulla rather than to give the exact shape of any hair which might be cross sectioned. The serial sections have usually been taken at uniform distances along the hair. Cross sections of hairs which are enlarged only in the distal end show one or two sections of the finer base and the remainder are of the enlarged portion.

* Mathiak, H. A. A Rapid Method of Cross-Sectioning Mammalian Hairs. Jour. Wild. Management. (Accepted for publication). (See Appendix).

The drawings are of cross sections taken at regions some distance apart. Therefore where two adjacent cross sections are shown to vary widely in shape, in the actual hair, intergradations between the two shapes must have existed. Cross sections of short hairs should be taken at smaller intervals than in long hairs since the shape of the cross sections may change much more quickly in a given distance. All drawings progress from the base of the hair at the left to the tip at the right. Identification is facilitated by performing the various operations in a standard, systematic order. When imbedding entire hairs, the base of the hair is conveniently grasped with a fine-pointed forceps and the hair laid on the celluloid with its base to the right end of the stick of balsa wood. After the sections have been sliced, they can be placed on the slide in serial order and examined from the base to the tip of the hair, comparing them with the Figures when necessary.

Usually the basal and distal ends of a hair can be determined with the naked eye or with the aid of a hand lens. Most of the hairs with noticeable taper are of maximum diameter somewhere in the distal half of the hair although tail hairs are sometimes a little coarser in the basal half. Many times the terminus of the hair at the base is conspicuously heavier than the tip which ends in a fine point. Some hairs are of equal fineness at the base and tip. Then the microscope must be resorted to. The distal end of a hair is told by the fact that it is always the distal portion of an individual scale

that always overlaps the basal end of the adjacent scale. The basal end of the hair either terminates with a broken surface or in a bulbous root.

Scale Examination. Saxinger and Herzog, both referred to by Hardy (8), developed a quick method for determining the form of cuticular scales. Their method is to place a thin coating of a plastic material on a slide, press the hairs into the plastic substance, and allow it to harden. The hairs are then removed and the negative impression of the scales thus produced examined under the microscope. The celluloid solution used in Cross-sectioning hairs serves well as the plastic material. This operation is not difficult to perform after a little experimentation with the viscosity of solution used and the time to lay the hairs on the celluloid. It does not matter how hard the celluloid becomes since only the lower portion of the hair is in contact with it and the hair can be removed without difficulty.

Hardy (8) and Manby (12,13) present modifications of this method by which positive impressions of the scales can be studied. The simplest method given is to attach the ends of the hairs to the slide so that the hair is in contact with the slide. A drop of celluloid solution is placed along the hair and allowed to dry. The hair is then torn out, the slide inverted, and the impression studied with a microscope. To prevent breaking, the hairs should be pulled out of the celluloid before it becomes too hard. These methods were developed

principally to facilitate photography of the scales which requires that the images be sharply defined.

For the purpose of the key, it is not essential to obtain clear-cut images of the scales. The hairs can be laid in the celluloid without regarding the depth to which they are immersed. If cover slips are used in the place of slides, the high power of the microscope can be used to better advantage. It is not necessary to fasten the hairs to the cover slip or have the lower surface of the hair in contact with the glass. Only in a few genera is the scale form of guard hairs adequately characteristic to identify the hair with certainty. In these cases it is always the scale form in the basal portion of the hair that is desired. The scales at varying distances along any one guard hair will show a great diversity of form, but the scales at corresponding regions of the same type of hair are fairly uniform in structure. In the species identified by scale structure, it will be found that some hairs have the characteristic scale form for only a short distance near the base. Therefore, when obtaining scale structure, four or more hairs should be imbedded at one time to insure a reliable representation of scale form.

KEY

It seemed desirable to divide the key into two Divisions. Size relationships between hairs in the two groups is one factor favoring their separation, Division I containing only mammals with fine, relatively short hairs. There is also a similarity in the manner of occurrence, hairs in Division I practically always being found in considerable numbers, as in feces and pellets. Some of these species are rather abundant and being small, they are generally ingested entire when taken as food, thus accounting for the abundance of hairs.

The key, it will be noted, consists of a key proper and interspersed Notes which follow each species as it appears in the key. The key proper contains the most distinctive characteristics and aims to keep the amount of time required to identify a hair to a minimum. The Notes consist of supplemental information to help verify identifications. Some of the Notes are of a rather general nature. Thus fur hairs are briefly described as they appear on the middle of the back, no account being taken of the variations at different regions of the body. Moderate use of the key should permit one to ignore the notes in many instances.

Precise instructions as how to proceed to identify a hair sample cannot be given. For longitudinal examination, it is an easy matter to mount several hairs of each type which

may be present in the sample. This is probably the first step to be taken since some species can be identified thus at once. Scale form is best determined ^{by imbedding} a number of the larger hairs and examining the scale images of these hairs. Scale form should not be judged merely on the basis of one hair. Cross sectioning requires more time so that in Division II usually only one hair is sectioned. A general rule is to section a hair of the largest average size represented in the sample.

The most profitable way to familiarize one's self with the key is to first work with known samples, comparing, comparing the cross sections, scales, and medullae with the descriptions in the key. Many features, such as the scales in the genus Mustela, have to be seen but once to be remembered. A person's own familiarity with the mammals is often helpful. Thus the short, distinctly banded hairs of a ground squirrel would hardly be even considered as belonging to a skunk or muskrat.

DIVISION I

This division includes the hairs of the moles, shrews, bats, flying squirrel, mice, and very young brown rats. The hairs of these mammals are short and fine and usually have a silky feeling and appearance. The maximum length is 22 mm. and the maximum diameter 110 micra, but a majority of the hairs will be less than 15 mm. long and 60 micra in diameter. These size limits apply only to samples containing several hundreds of hairs. Otherwise a small group of head or leg hairs of other small mammals, such as the least weasel, might be included in this division whereas they are properly placed in Division II.

The hairs often have many nodes and internodes. The medulla of the fur hairs, when present is discontinuous. The hairs of these mammals are easier to identify than the hairs of many of the larger mammals providing hairs from only one species are included in the sample. When the hairs of several species are mixed together, numerous xylene mounts are required in order to make certain that the hairs of all species present are noted.

Samples of the hairs of these small mammals are most often found in feces and pellets and usually contain several hundreds of hairs per sample. The key is based on this assumption that a goodly number of hairs are available. Cross sections are obtained not of a single hair but of a representative

cluster of the largest hairs in the sample. The hairs are imbedded as a group and enough slices are made as are necessary to cut through the region of greatest diameter of the largest hairs. Since it is only necessary to determine the shape of the largest cross sections, serial illustrations of the cross sections have not been given.

Hairs from these mammals, especially those considered as buffer species will be encountered very frequently in food habits studies. Pellets of the larger hawks and owls contain the remains of more than one mammal and since the skulls are ejected with the hairs, it is probably easier and more accurate to base the identification on the skulls when a large number of pellets are to be analyzed. Skulls give a better quantitative analysis since hairs can provide information as to the species present, but not as to the number of individuals present in a single pellet. It would be difficult to detect all the hairs of these small species when the hairs are matted together and well mixed in a pellet, particularly those with circular or oblong cross sections since practically all species have at least a few hairs with cross section of these shapes. Skulls also make it easy to identify the species in a group, such as the mice, where the hairs appear very similar in structure.

A different problem is presented in feces in which skulls are usually absent, but the hairs are not intermixed to such a great extent. Here hairs must of necessity be used as a basis for identification.

DIVISION I

- 1 Larger hairs often having the rodent base 2
- 1,1 Larger hairs never or only very rarely having the rodent base . 4
- 2 Cross sections of many of the larger hairs flattened and concave on one side as shown in Fig. 22. 2,2

Field mouse, Microtus sp.
 Deer mouse, Peromyscus sp.
 House mouse, Mus musculus.
 Very small brown rats, Rattus norvegicus.

NOTES. Hairs fine, maximum diameter about 80 micra, usually less than 18 mm. in length. Hairs do not have distinct bands of colors. Fur hairs may have nodes and internodes. Medulla at internodes sometimes continuous but usually discontinuous.

- 2,2 Hairs not with cross sections flattened and concave on one side as shown in Fig. 22. 3
- 3 Fur hairs with nodes and internodes. Cross sections of guard hairs always convex, bluntly-oblong to circular as in Fig.23. Hairs usually less than 12 mm. in length and 110 micra in dia. 3,3
 - Meadow jumping mouse, Zapus hudsonius hudsonius.
- 3,3 All hairs without nodes and internodes. Outline of largest cross sections convex or very slightly concave on one side as seen in Fig. 24.
 - Flying squirrel, Glaucomys volans volans.
- 4 All hairs very fine, usually less than 20 micra in diameter. Hairs without nodes and internodes. Scales usually coronal and are very prominent in some hairs. (Fig. 12). Medulla almost always lacking. . . . 4,4
 - The bats, Chiroptera, Six species.
- 4,4 Larger hairs more than 20 micra in diameter. Many of the hairs with nodes and internodes. All hairs with prominent medullae. 5

5 Hairs very fine with the distal node greatly enlarged (as seen under high power) in some hairs. Enlarged portion lightly pigmented with brown granules, the medulla lacking or fragmental. Only rarely is the medulla discontinuous in the basal half of the enlarged distal node.5,5

Prairie mole, Scalopus aquaticus machrinus.

NOTES. Distal node up to 75 micra in diameter. Cross sections of the largest hairs convex. All hairs with numerous nodes and internodes. Unenlarged portion of protective hairs and the fur hairs have a discontinuous medulla.

5,5 Hairs not with the distal node greatly enlarged with the medulla fragmental or lacking in the enlarged portion. . . . 6

6 Largest cross sections shaped as in Fig. 25. . . .6,6

Shrews, three species. Soricidae.

NOTES. Hairs usually less than 55 micra in diameter and 10 mm. in length. Medulla discontinuous except at the internodes where it commonly becomes continuous.

6,6 Cross sections of hairs never shaped as in Fig. 25. . . . Scales at base of guard hairs long and sharly pointed as seen in Fig. 14. Cross sections largest hairs circular.

Star-nosed mole, Condylura cristata.

DIVISION II

This division is concerned with the remaining mammals whose hairs have been arranged in the key somewhat according to the ease of identification. A majority of the wild mammals have hairs with features distinct enough to permit generic or specific classification. In contrast, the hairs of the domesticated mammals are more difficult to describe and identify, both because of the many breeds of animals and because the hairs themselves lack distinctive characteristics. However, with the exception of the dog, these hairs will not be encountered very often in zoological studies. A few hairs of the wild mammals are of such character that they cannot be included in the key. These hairs are the smaller head and leg hairs and the tail hairs of certain species. The medulla is often much reduced in size and the cross sections tend to assume circular or bilaterally symmetrical shapes. Therefore, unless the scales are distinctive, the hairs are very difficult to identify. All hairs which cannot be identified with reasonable certainty have been placed in a miscellaneous group at the end of the key. The combined characters given in the key and more detailed notes should prevent any hairs belonging to the miscellaneous group from being keyed out in the preceding part of the key.

DIVISION II

7 Hairs fine and exceedingly curly, usually found in a tightly matted mass. All hairs of approximately the same diameter. Medulla usually lacking. A greater part of an individual hair is without taper. Scales not conspicuously thickened. . . . 7,7

Sheep.

7,7 Hairs not exceedingly curly. Or hairs not very fine. Or hairs with a well developed medulla. 8

8 Some intermediate hairs in longitudinal view appearing to be made up of squares and rectangles, the sides of which are joined at the corners (Fig. 7). The rectangles lie in distinct longitudinal rows with an occasional row going off at a tangent. A different effect may be seen in other hairs in which the cubical cells themselves can be seen lying in longitudinal rows. Guard hairs do not have these rows of cells, but they are much less numerous than the intermediate hairs so that it would be impossible to obtain a sample consisting only of guard hairs. 8,8

Cottontail rabbit, Sylvilagus floridanus mearnsii
Snowshoe hare, Lepus americanus spp.

8,8 Medulla in longitudinal view not appearing to be made up of squares and rectangles or longitudinal rows of cubical cells. 9

9 Guard hairs with long-pointed scales extending to a variable distance from the base (Fig. 14). In some hairs the scales may be more blunt pointed but can still be recognized as Mustela by a few scales (Fig. 15) which will have very straight edges and a sharp point. Cross sections usually oblong and bilaterally symmetrical. 9,9

Mink, Mustela vison mink.
Least weasel, M. rixosa alleghensis.
New York Weasel, M. n. noveboracensis.

NOTES. Hairs never banded. Medulla nodose continuous except at the very tip where it becomes discontinuous. A few tail hairs may be circular in cross section and without the characteristic scales.

9,9 Guard hairs not with long^g pointed scales in the basal portion of the hair; or hairs with irregular cross sections or with distinct bands of colors. 10

10 Outline on cross sections concave on one side for at least 1/6 of the length of the hair. Hairs often having the rodent base. Or scales at the base of the larger hairs similar to those shown in Figs. 16 and 17. for at least a distance of 200 micra. 11

NOTES. Tail hairs of the chipmunk have scales somewhat similar to this, but they do not occur to a distance of 200 micra along the shaft. A very few guard hairs of the fox may have cross sections concave on one side for a short distance, but the medulla is homogeneous continuous and the scales at the base of the hair may be similar to those in Fig. 18. Pile hairs of the rabbit have scales similar to those in Figs. 16 and 17, but the very distinctive medulla should prevent their being placed in this group. Cross sections of rabbit hairs may be concave on one or two sides.

10,10 Outline of cross sections not concave on one side for at least 1/6 of the length of the hair, scales never as in Figs. 16 and 17. 14

11 Scales at base of guard and intermediate hairs similar to those shown in Figs. 16 and 17. 11,11

Red squirrel, Sciurus hudsonicus loquax.
Gray squirrel, S. carolinensis leucotis.
Fox squirrel, S. niger rufiventer.

NOTES. Fur hairs have a discontinuous medulla and a pigmentless cortex. Many of the hairs have cross sections concave on one side in the basal portion of the hair. The darkly pigmented guard hairs have the typical scales, but the cross sections are oblong and convex in outline.

11,11 Scales at the base of the guard or intermediate hairs not similar to those shown in Figs. 16 and 17. 12

12 Cross sections concave on one side for practically the entire length of the hairs, such as in Figs. 26 & 27.

12,12

Ground squirrel, Citellus t. tridecimlineatus.

NOTES. Fur hairs commonly without a medulla. Some may have a few fragments of one or a discontinuous medulla for a short distance near the tip of the hair. Cortex has numerous pigment granules.

12,12 Cross sections not concave on one side for practically the entire length of the hair. 13

13 Scales at base of hair often conspicuous in a xylene mount and roughly appearing diamond shaped (Fig. 19). Cross sections of basal portion of hair much flattened and concave on one side as in Fig. 28. 13,13

Brown rat, Rattus norvegicus.

NOTES. The brown rat also has a set of longer guard hairs which have the same scales at the base, but the cross sections are circular. These darkly pigmented hairs are very similar to some leg hairs of the skunk.

13,13 Cross sections basal half of hair not as in Fig. 28. Scales at base of hair not as in Fig. 19.

Southern woodchuck, Marmota monax monax.
Rufescent woodchuck, M. monax rufescens.

NOTES. Cross sections of basal and distal third of hair elliptical while the mid-region has cross sections concave on one side as in Fig. 29. Other hairs with the basal half of hair having cross sections concave on one side while the cross sections of the distal half are elliptical. Many hairs have a white band about 5 mm. long near the tip of the hair with pigment granules in the extreme tip. Such white tipped hairs with pigments in the extreme tip are found only in the woodchuck and the ground squirrel, but the tail hairs of the ground squirrel are concave on one side for most of the length of the hair. Some belly hairs may have a very clear diffuse reddish pigmentation which is very characteristic although the cross sections are convex.

- 14 Many hairs with the rodent base. Cross sections very regular, being elliptical in the basal half and circular in the distal half (Fig. 30). Cortex of many fur hairs without pigment granules but may contain scattered air spaces. 14,14

Chipmunk, Tamias striatus lysteri.

NOTES. Hairs short, rarely more than 20 mm. long. Tail hairs are circular or nearly so in cross section. Some fur and intermediate hairs have a diffuse pigmentation in the distal end. Cortex in fur hairs is relatively thin.

- 14,14 Cross sections not regularly elliptical in the basal portion and circular in the distal portion. Hairs usually without the rodent base. 15

- 15 Medulla small (Fig. 5), usually less than 1/3 as wide as the hair. Cortex has numerous pigment granules ranging from light to dark brown, lying in longitudinal streaks. In the lighter pigmented hairs, numerous irregular chambers can be seen in the medulla. The walls of the chambers have a high luster where they adjoin the cortex. Cross sections narrowly elliptical and bilaterally symmetrical as seen in Fig. 31. 15,15

Muskrat, Ondatra zibethica.

- 15,15 Cross sections not as in Fig. 31 with a small, nodose continuous medulla, or hairs with distinct bands of colors. 16

- 16 Larger hairs all white, medulla continuous, grayish, and often irregular in cross section (Fig. 32). Scales fairly conspicuous in xylene mount. Cortex of fur hairs without pigments in the basal 2/3 of the shaft. There is a set of smaller intermediate hairs with dark pigment granules. These hairs are often enlarged only in the distal half. Cross sections distinctly flattened on one side as in Fig. 33. 16,16

Opossum, Didelphis virginianus virginianus.

- 16,16 Medulla of white hairs never with lobes as in Fig. 32. Intermediate hairs not with cross sections flattened on one side as in Fig. 33. Or hairs with more than two bands of colors. 17

- 17 17 Medulla composed of distinct chambers, roughly hexagonal in shape as seen in Fig. 20. Under high power the walls of the chambers have a high luster where they come in contact with the cortex. In most hairs the cortex is very thin with the medulla occupying almost the entire shaft. . . . 17,17

White-tailed deer,
Odocoileus virginianus borealis.

NOTES. Cross sections circular to oval. In small hairs from the head and legs, the cortex may be thicker, but the medullary chambers are still distinctive. Hairs may be over three hundred micra in diameter.

- 17,17 Medulla not with distinct, clear-cut chambers, roughly hexagonal in shape or the cortex is never so thin as to be practically invisible. . . . 18

- 18 Cross sections elliptical and bilaterally symmetrical with a relatively thick cortex as seen in Fig. 34. Intermediate hairs with symmetrical scales in the basal portion of the hair as seen in Fig. 21. Medulla homogeneous continuous and coarsely granular. As viewed longitudinally, the edges of the medulla are often not parallel to the edges of the hair. Hairs never all white. Medulla of fur hairs generally lacking or fragmental, rarely discontinuous. Cortex with numerous pigment granules. An excellent point to be observed in the cross sections of some of the darkly pigmented hairs is a narrow strip of pale yellow at the periphery of the cross section.

Raccoon, Procyon lotor lotor.

The remaining hairs are the most difficult to describe and identify. The miscellaneous group includes hairs of the following species:

1. Badger, Taxidae taxus taxus.
2. Skunk, Mehitis nigra.
3. Fox, Vulpes fulva.
4. Coyote, Canis latrans.
5. Dog, C. familiaris.
6. Cat, Felis domestica.
7. Cow.
8. Horse.
9. Man.
10. Pig.
11. Tail hairs of the squirrels, Sciurus.
12. Tail hairs of the chipmunk, Tamias striatis lysteri.
13. Some of the tail hairs of the raccoon, Procyon l. lotor.
14. Some tail and belly hairs of the woodchuck, Marmota spp.
15. Small head and leg hairs of all species.

It does not seem possible to describe these hairs in key form. There is too much similarity between various hairs of certain of these species. In several of the species, each individual may have many different kinds of hairs. Thirdly because the hairs themselves have neither scales, cross sections, or medullae which are distinct enough to describe and permit

positive identification. Usually numerous combined characters must be taken into consideration in order to identify these hairs, when it is at all possible to do so. Many of these hairs can, however, be identified by comparison or through personal familiarity with the hairs. Notes are given for some of these hairs which may help identify the species.

Hairs all white, all brown, or with two or three bands of brown and white. Large guard hairs stiff and bristle-like. Some of them, when observed under the microscope, are seen to have nodes and internodes in the basal portion. Medulla homogeneous continuous. Cross sections often irregular in shape as seen in Fig. 35. Some hairs with most of the cross sections regular and oblong with a slit-like medulla.

Fur hairs with a discontinuous, fragmental, or continuous medulla, usually less than $1/3$ of the width of the hair. Cortex of many fur hairs is without pigment granules.

Badger, Taxidae taxus taxus.

Hairs all white, all dark brown, or rarely with a band of brown and white. Medulla is homogeneous and finely granular, but often concealed in the darkly pigmented hairs. Cross sections all oblong, all circular, or circular in the basal portion and oblong in the distal portion. Fur hairs white or with brown pigment granules in the cortex. Medulla about $1/3$ as wide as the hair.

Skunk, Mephitis nigra.

Intermediate or small guard hairs with scales as seen in Fig. 18. Medulla homogeneous. Fur hairs with a discontinuous medulla. Cross sections circular to oblong, sometimes flattened on one side. These hairs will not be confused with the opossum because the cross sections are circular in the basal portion while in the opossum they are flattened at the base of the hair.

Fox, Vulpes fulva.

Coyote, Canis latrans.

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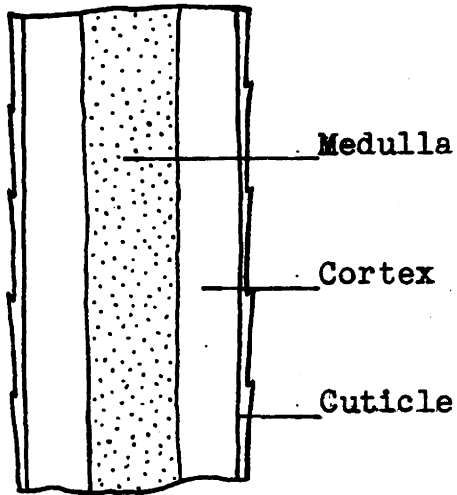


Fig. 1. Diagram of a longitudinal section of a hair shaft.

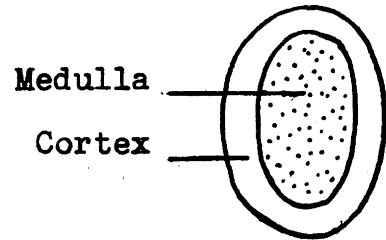


Fig. 2. Diagram of a cross section of a hair. Usually the cuticle is too thin to be seen in cross section.



Fig. 3. Discontinuous medulla of a fur hair with a relatively thin cortex.



Fig. 4. Discontinuous medulla of a fur hair with a relatively thick cortex.

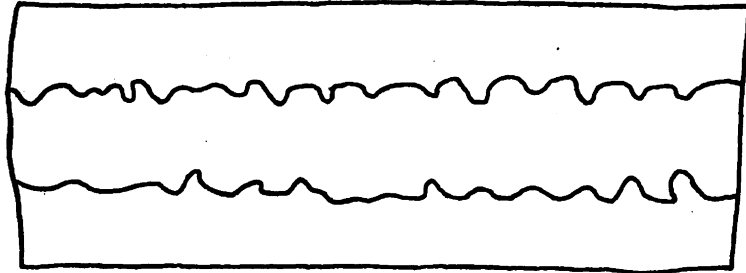


Fig. 5. Outline of a nodose continuous medulla of a muskrat guard hair.

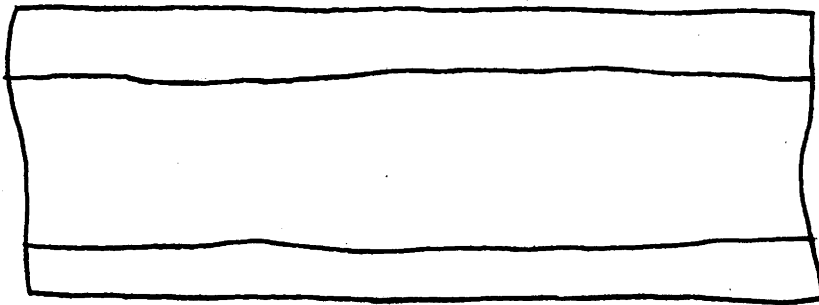


Fig. 6. Outline of a homogeneous continuous medulla.

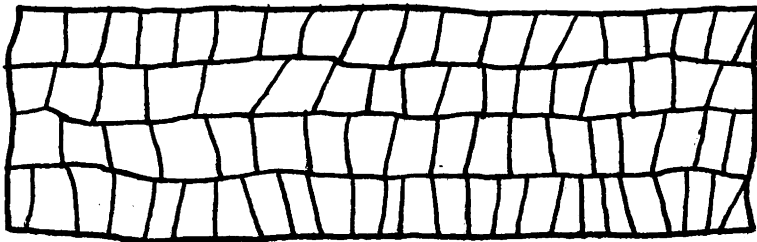


Fig. 7. Rabbit intermediate hair with a chambered medulla and a thin cortex.

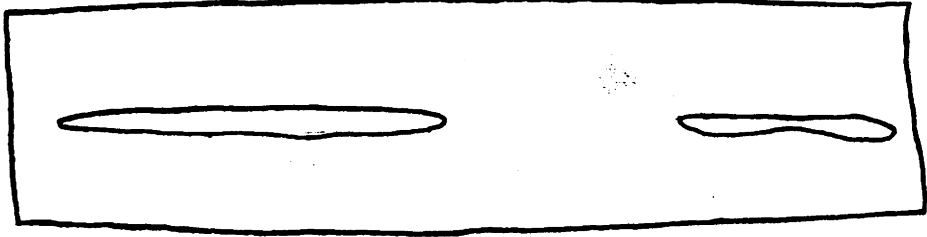


Fig. 8. Fragmental medulla of a human hair.

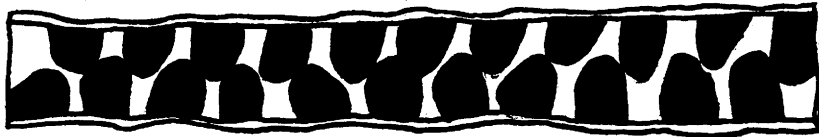


Fig. 9. Compound medulla or one type of the rodent base.

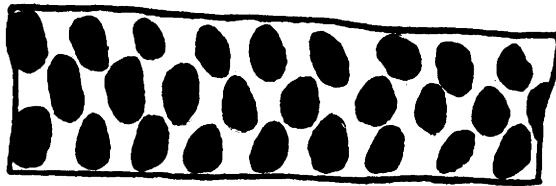


Fig. 10. A compound medulla

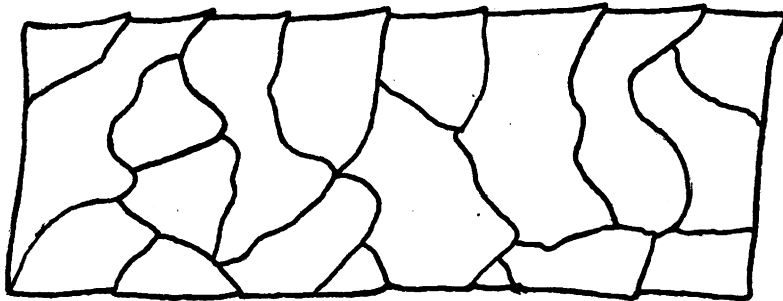


Fig. 11. Imbricate scales of a fox hair.

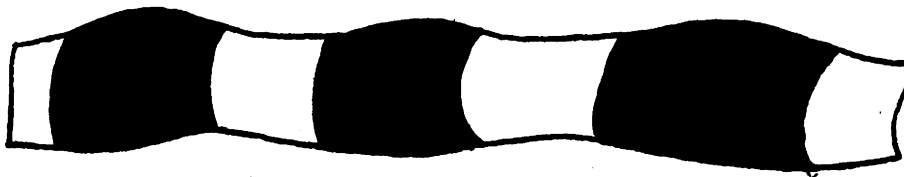


Fig. 12. Heavily pigmented coronal scales of a bat hair.



Fig. 13. An internode having a continuous medulla with a portion of two nodes.

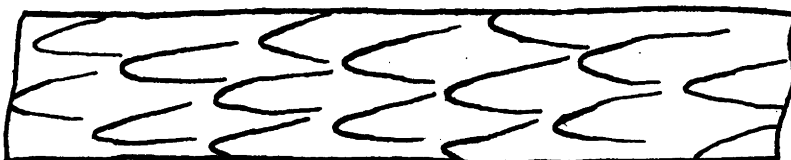


Fig. 14. Long-pointed scales such as are found in some hairs of the star-nosed mole and members of the genus Mustela.

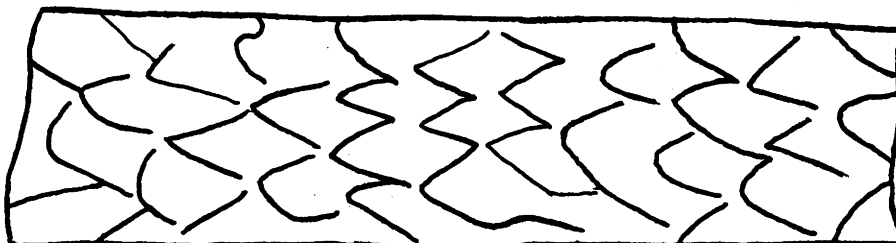


Fig. 15. Sharp, pointed scales found in some hairs in the genus Mustela.



Fig. 16. Scales of certain hairs of the squirrels, Sciurus.

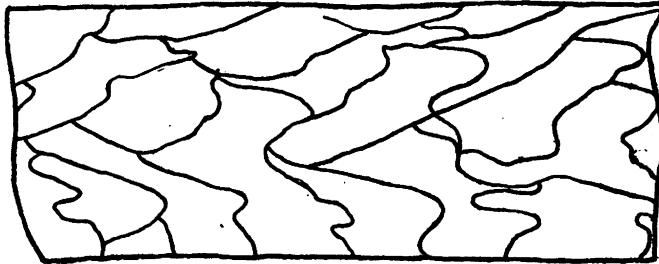


Fig. 17. A variation in the scales of squirrel hairs.

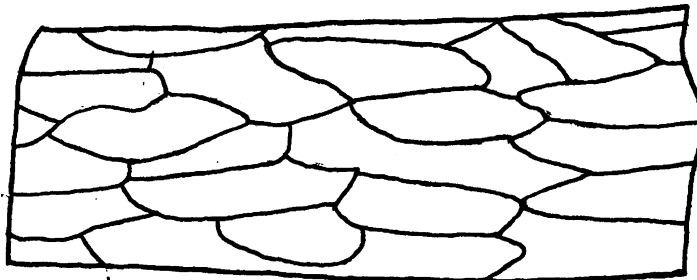


Fig. 18. Scales as seen in some hairs of the fox and coyote.

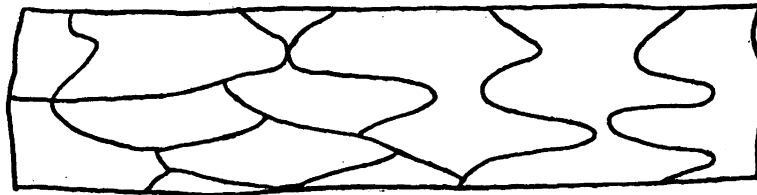


Fig. 19. Roughly diamond shaped scales of the brown rat.

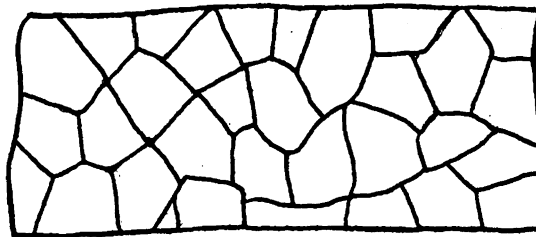


Fig. 20. Roughly hexagonal shaped chambers in the medulla of a deer hair.

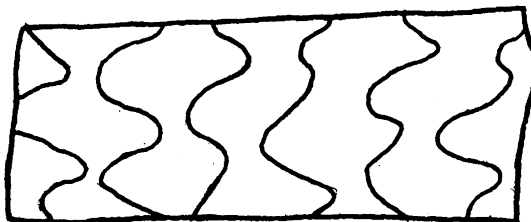


Fig. 21. Scales of an intermediate hair of the raccoon.

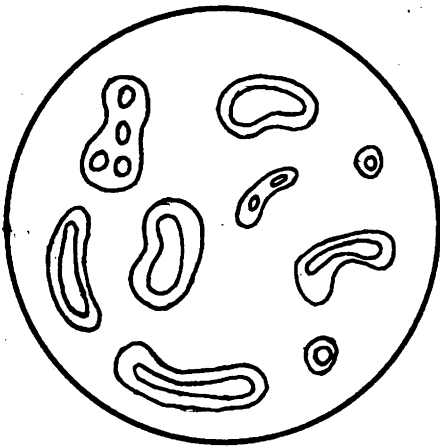


Fig. 22. Characteristic cross sections of field mice, deer mice, house mice, and very young brown rats.

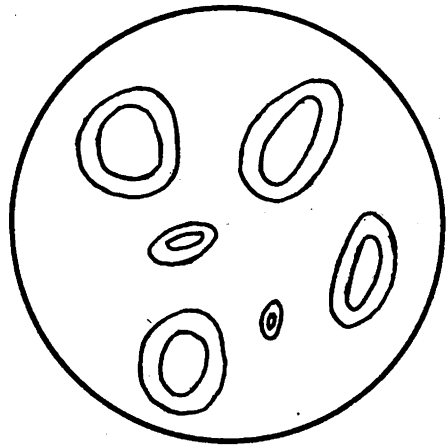


Fig. 23. Cross sections of guard hairs of the jumping mouse.

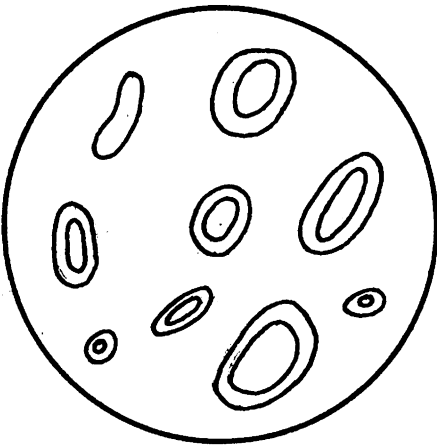


Fig. 24. Cross sections of body and tail hairs of the flying squirrel.

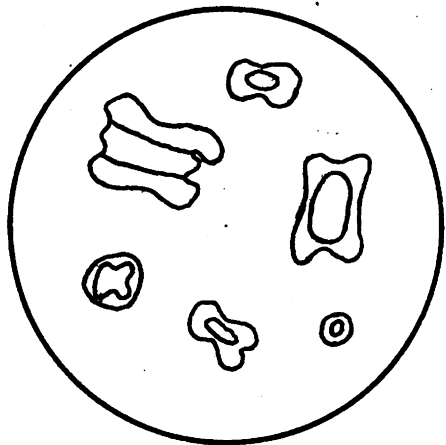


Fig. 25. Distinctive cross sections of shrew hairs.

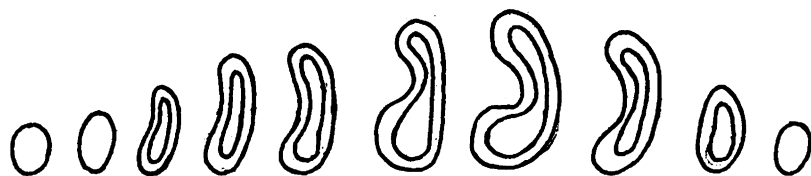


Fig. 26. Back hair of ground squirrel.



Fig. 27. Tail hair of a ground squirrel.

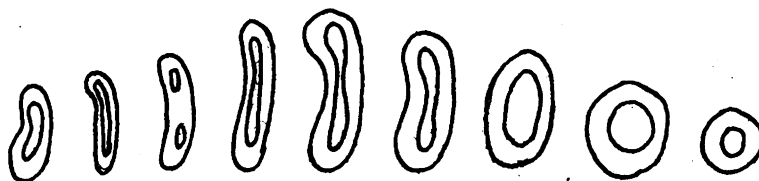


Fig. 28. Intermediate hair of the brown rat.

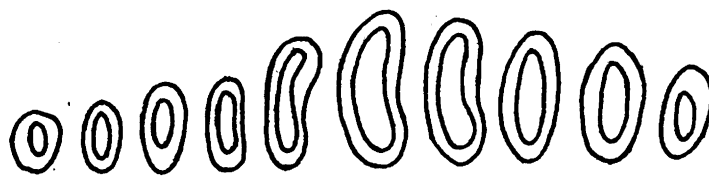


Fig. 29. Guard hair of the woodchuck.



Fig. 30. Guard hair of the chipmunk.

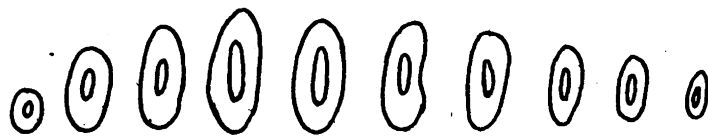


Fig. 31. Guard hair of the muskrat.

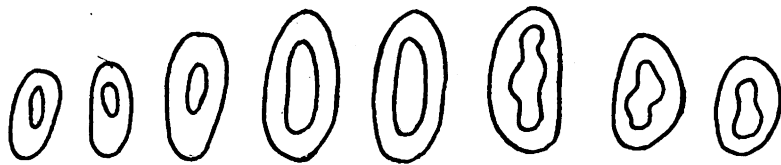


Fig. 32. Large white guard hair, opossum.

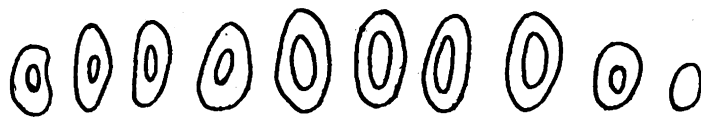


Fig. 33. Pigmented intermediate hair, opossum.

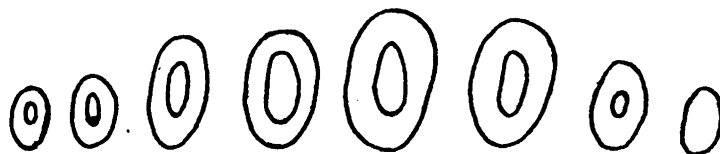


Fig. 34. Guard hair of the raccoon.

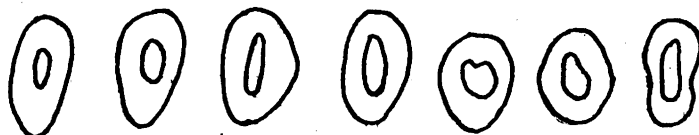


Fig. 35. Guard hair of the badger.

APPENDIX

A Rapid Method of Cross-Sectioning Mammalian Hairs

Harold A. Mathiak

Hair samples are frequently encountered in connection with life history studies, food habits research, and in isolated cases of mortality observed in the field. Cross sections of the hairs often prove of material value in determining the identity of the mammal involved. In some mammals, for example the shrews, the shape and structure of the cross sections of the hairs are much more distinctive than the appearance of the hair as viewed longitudinally. Especially is this true when it is known from which portion of the hair the cross sections are obtained.

Several methods of cross-sectioning hairs have been used in the past, the most intricate being the use of rotary or sliding microtomes. However, many workers do not have access to microtomes, and furthermore, the amount of time required by the microtome method is far too long for practical purposes.¹ Hardy mentions Hotte's method of building up successive layers of celloidin, bayberry wax, and paraffin about individual hairs in order to section them. Dearborn² rolled softened paraffin between the palms of the hands, forming a cylinder. The cylinder was cut lengthwise, hairs were inserted between the

-
1. This method is discussed in detail in Guyer's (1) Animal Micrology.
 2. From verbal description of the method by H. M. Wight.

halves which were firmly pressed together again, sections then being sliced with a razor blade.

Williams (3) describes a method developed and used at the Food Habits Research Laboratory, Denver, Colorado, by which individual hairs can be sectioned. The pith from the stem of a plant, such as ragweed, is split lengthwise, and the hairs are placed between the halves parallel to the longitudinal axis. The halves are sealed together with gum-arabic mucilage which is allowed to dry. Sections are then cut with a sharp razor blade. These sections can be mounted in Canada balsam for microscopic examination.

Recently an efficient, modified microtome with which an experienced operator can obtain cross sections of fibers in ten minutes was invented by Hardy (2). A group of fibers is washed in alcohol or ether, dried with blotting paper, and placed in a rectangular slot in a holder of the metallic device which is so constructed that the clump of fibers can be projected through the slot to any desired distance. Colored celluloid solution is applied to the ends of the fibers and allowed to dry, after which the sections of fibers and celluloid are cut off with a sharp razor blade and mounted in Canada balsam. By means of a screw propeller, the fibers are caused to project out to the desired distance for cutting, another coating of celluloid is applied, and the process repeated.³ The instrument was in-

3. Diagrams and a more complete explanation of how the device operates is to be found in Circular (2) No. 378, U.S. Dept. Agriculture. This instrument is now available at a price of \$35.

tended primarily for the study of fibers used in the textile industry and is admirably suited for that purpose since large numbers of cross sections of each sample of fibers are wanted. Sections may be cut so thin that even the shape of pigment granules can be seen.

In the course of present studies the writer has developed a new technique for cross-sectioning hairs which seems satisfactory. It works equally well for one or several hairs of any size. They are visible during the entire operation so that cross sections of any desired portion of a single hair can be taken. Guard hairs exhibit much more individuality than fur hairs, and since the shape of the cross sections of guard hairs may vary widely from base to tip, it is essential that the region from which the cross sections are cut be known.

The method is inexpensive, requiring razor blades, a pink solution of celluloid in acetone, and balsa wood, the latter purchasable at stores carrying model airplane supplies.⁴ While different pieces of balsa wood may vary in hardness, none of it is too hard to cut with a razor blade. When it is desired to section small individual hairs, the long strips of wood can be cut into sticks about four inches long and halved longitudinally with a razor blade.

In making the celluloid solution, first dissolve a red or pink dye (these colors apparently give the best results) in acetone, and then add pieces of celluloid until the solution

4. In Ann Arbor strips of balsa wood $1/8 \times 1/4 \times 18$ inches cost one cent each.

is of the right consistency. There can be considerable range in the viscosity of the solution, thin solutions evaporating faster and thicker solutions holding the hairs more firmly. The solution should be colored only a very pale pink, for the dye will become more concentrated when the acetone is allowed to evaporate. Too much dye in the celluloid interferes with transmission of the light and reduces definition. Congo red, carmine, or any red dye is suitable. Dyes not soluble in acetone can be added after being first dissolved in alcohol. The celluloid solution is most conveniently kept in a small, tightly stoppered bottle in which a brush is attached to the stopper. Finger-nail polish can be substituted for the celluloid solution by those wanting to section only a few hairs.

Imbedding is accomplished by placing a coating of celluloid on a stick of balsa wood, and then laying the hairs on the sticky solution parallel to the long axis of the stick as seen in Fig. 1, A. Additional celluloid is placed on top of the hairs and allowed to dry. The sections can be sliced in from five to ten minutes, depending on the amount and viscosity of the solution used. Hardening of the celluloid can be hastened by mildly heating it over an electric lamp after most of the acetone has evaporated. Heat cannot be applied immediately because of the formation of large bubbles. No time will be lost waiting for the celluloid to harden if five or more samples of hair are imbedded before any sectioning is done.

A razor blade held in a vertical plane is used with a slicing motion to cut through the celluloid, hairs, and wood. Sections (shaped as in Fig. 1, B) can be varied from three-tenths to one millimeter in thickness, six-tenths millimeters being generally most suitable.⁵ The sections are arranged in serial order on a slide and examined under a microscope with transmitted light. A thin film of oil on the slide will prevent any disturbance of the extremely light pieces of balsa wood. Long hairs can be cut into shorter lengths which, if imbedded in consecutive order, will give serial sections of the entire hair.

Although low power discloses structural features sufficiently well in most instances, high power can be used for the examination of the smaller hairs and in the event that measurements are to be taken with an ocular micrometer. Small hairs will be found imbedded entirely within the celluloid while very large hairs may project above the general level (Fig. 1, C) since the solution greatly decreases in volume upon drying. In either case the celluloid is so rigid that the cross sections are obtained without distorting the hair. The celluloid is colored a light pink to differentiate it from the wood and to improve optical effects. A brilliant illumination with the celluloid and hair to one side of the microscopic field, as shown in Fig. 1, D, gives the best definition, the wood cutting out much of the light and preventing eye strain. Clearing the

5. Thinner sections seem to be better for white or densely pigmented hairs.

hairs with an oil is not necessary, the medulla, cortex, and character of the pigmentation being discernible in the sections as cut. Cross sections from specimens of known identity can be filed in small vials for future reference.

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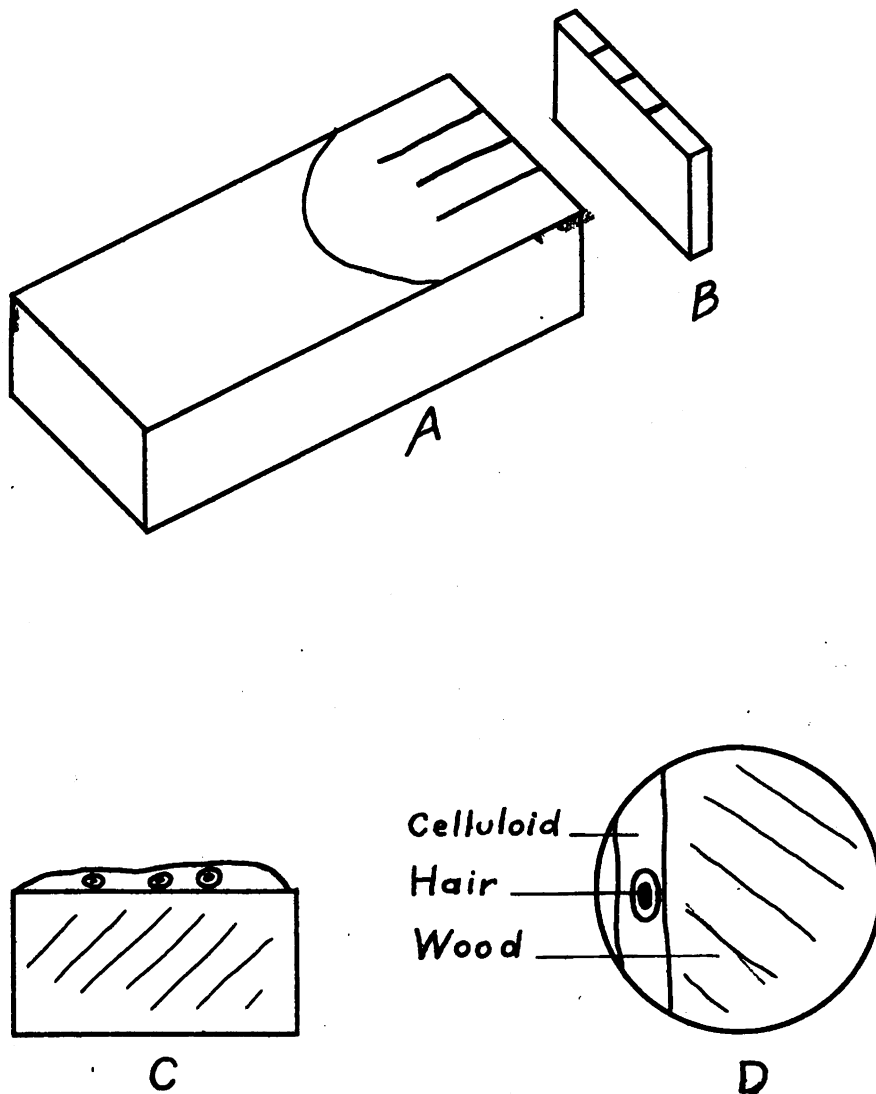


Fig. 1. A, Small stick of balsa wood showing hairs in celluloid, X 2; B, a section as cut off, X 2; C, same section X 3 with size of hairs exaggerated; D, diagram of a section as it appears in the microscopic field.

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