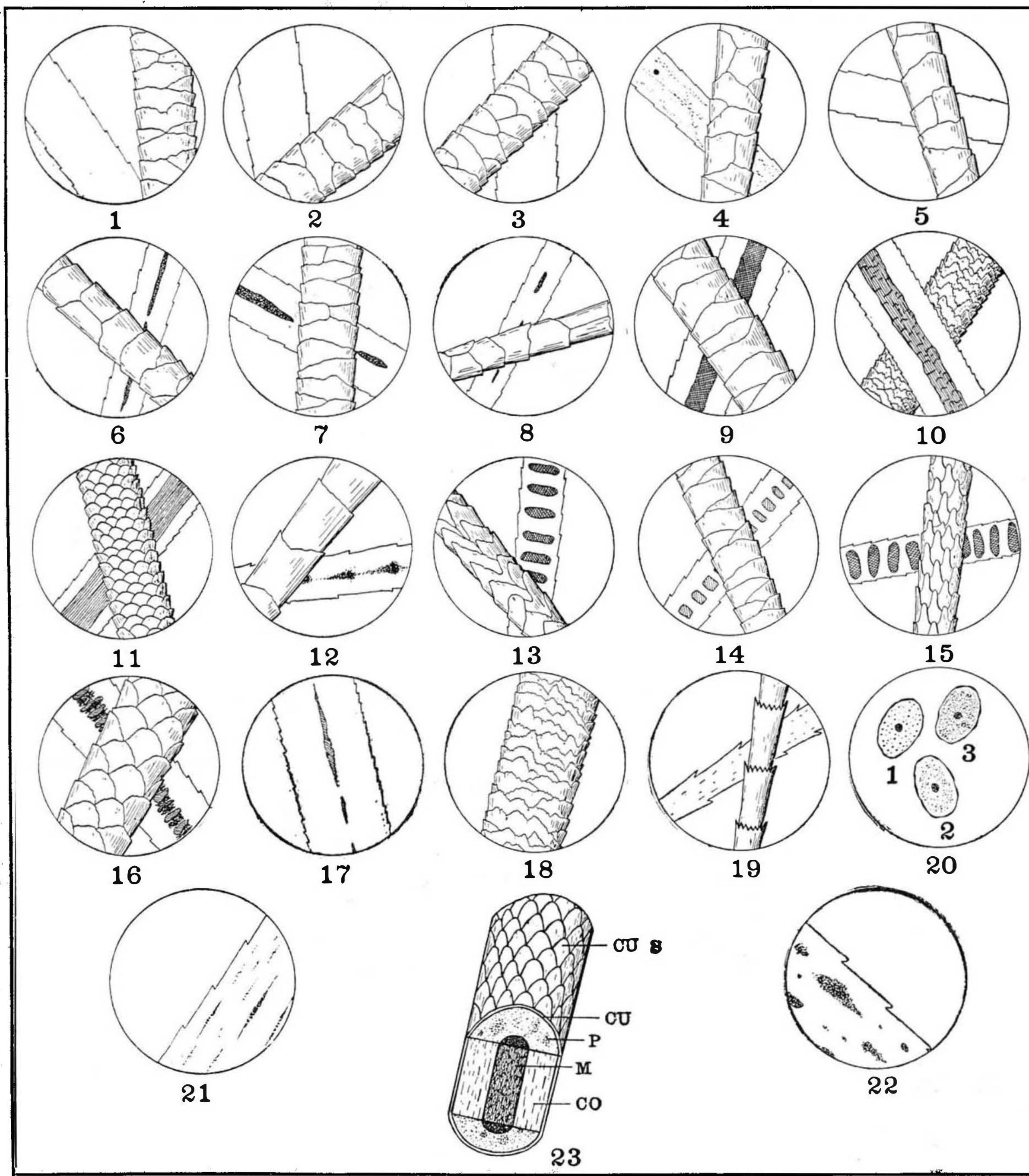
Hairs that Make Fabrics

The Microscopic Identification of Mammal Hairs Used in the Textile Industry

By Leon Augustus Hausman, Ph.D.

THE textile industry is of great antiquity, and as the art of weaving preceded that of spinning, so the art of felting antedated both. Hence felted fabrics represent man's earliest attempts at textile fabrication. The inhabitants of the middle and northern regions of Asia apparently employed felts of various sorts from a period of very remote antiquity as articles of clothing, or in the construction of their habitations. Most of the writers of classic times refer to felt more often than to woven products, and some describe the process of its manufacture. Among many of the ancient peoples heavily constructed textiles, predominantly felts, were used for the manufacture of hats, outer garments to shed the rain and snow, and often as a species of armor.



(1) American Southdown sheep—40μ; (2) American Shropshire sheep—30μ; (3) Dorset sheep—33μ; (4) Angora goat, source of mohair—20μ; (5) Bactrian camel—19μ; (6) Guanaco—18μ; (7) Alpaca—28μ; (8) Vicuna—11μ; (9) Cow—47μ; (10) Horse—130μ; (11) Virginia deer—103μ; (12) American beaver—18μ; (13) Hare—17μ; (14) American gray squirrel—18μ; (15) Domestic cat—16μ; (16) Badger—48μ; (17) Man—medulla of Caucasian female—50μ; (18) Man—cuticular scales of Caucasian female—50μ; (19) Intermediate bat—17μ. Figure 20 shows transverse sections through human hair-shafts, displaying contour of medulla and disposition of pigment granules: (1) blonde Norwegian female, (2) brunette American, (3) black Indian male. Figure 21 shows portion of hair shaft from brunet American, highly magnified, to show characteristic appearance of pigment granules in their method of massing. Figure 22 shows portion of fur hair-shaft from cat, with the same object. Figure 23 represents an ideal mammalian hair-shaft; see text for reference letters. In Figs. 1-19 the upper hair shows the cuticular scales, the lower the medulla

The more important mamma hairs, with sizes in micra; and some general structural characteristics

The fibers utilized in felting were largely those of animal origin, *e. g.* hair and wool, but with the advent of the arts of weaving and spinning, vegetable fibres came into use, and have since increased in importance as textile fibres. However animal hairs still hold the place of prime importance in the textile industry, not only in felting, but in spinning and weaving as well. Following these, in the descending order of their importance, come the fibres of vegetable ufacture, and of mineral origin, of artificial manderivation.

Up to the present time no systematic series of zoologically sound criteria for the indubitable identification of mammal hairs was to be had. In a recent contribution to the knowledge of the structure of mammalian hair (*A Micrological Investigation of the Definitive Hair Structure of the Mammalia, with Especial Reference to the Monotremata*, in press) the present author has pointed out that certain constant characteristics of the microscopic elements in the structure of the hair shaft are of importance from several zoological viewpoints. That the results of the application of these determinative criteria may be of practical value in the more rapid and certain identification of the various mammal hairs used in the textile industry, it is the object of this paper to suggest. With the present-day extraordinary increase in the number of the different kinds of fibres used as bases for textile fabrics, methods for the indubitable identification of fabric stuffs would seem to be of no small utility. Of the various classes of fibres used in textiles; artificial, vegetable, mineral, and animal, those of the latter class have given the most difficulty in accurate determination..

In order to appreciate the nature of the structural elements of the hair shaft which are made use of in identification, it will be necessary to pass briefly in review the structure of the typical mammalian hair. Hairs take their origin from the bases of relatively deep pits in the epidermis, or outermost layer of the skin, known as hair follicles, and, being added to from the base, push upward in a rod-like growth, of circular or elliptical cross section. The hair shaft consists of four structural units: (1) the *medulla* (M, Fig. 23), often commonly termed the pith from its analogous structure in plant stems, which is built up of many superimposed cells or chambers, and containing air spaces and sometimes small masses of pigment material; (2) the *cortex* (CO, Fig. 23), or shell, surrounding the medulla, and composed of many elongate, fusiform cells, coalesced together into a horny homogeneous mass, of hyaline texture and appearance; (3) the *pigment granules* (P, Fig. 23), to which the color of the hair is primarily due, scattered about within the corticular substance; and (4) the *cuticle* (CU, Fig. 23), or outermost integument of the hair shaft, lying upon the cortex, and composed of imbricated scales. It is the forms, anatomical relationships, and exact measurements of these four elements, together with the measurement of the hair shaft itself, in micra (1 micron = one one-thousandth of a millimeter, or about one quarter-millionth of an inch) which constitute the series of determinative criteria to which reference has been made.

Medullas fall into four great groups: (1) the *discontinuous* as in the hair of the domestic cat (Fig. 15); (2) the *continuous*, as in the hair of the cow (Fig. 9); (3) the *interrupted*, a type intermediate between the first two, as in the hair of horse (Fig. 10); and (4), the *fragmental*, as in the hair of the vicuna (Fig. 8). It will be noted that the hair of some species apparently lacks the medulla altogether, though minute dissociated traces exist in certain portions of the hair shaft.

The cortex element, as has been said, is of homogeneous, hyaline texture, and only under special complex treatments can be made to exhibit any structural characters. Hence, when used in description it is merely measured, as to thickness, between the medulla and the cuticle.

The pigment granules, when present in sufficient quantity, are of characteristic form, color, depth, and disposition within the cortex, and can be used as dependable coördinate criteria. (Figs. 20, 21, and 22.)

That structure which presents the most readily usable, though not necessarily the most dependable characteristics, is the cuticle, whose component elements, the scales, are of two diverse types: (1) the *imbricated interrupted* type, those which lie singly overlapping upon the hair shaft, like the shingles on a roof, or the scales on a fish (CU S, Fig. 23), as in the hair of the badger (Fig. 16); and (2) the *imbricated coronal* type, those which encircle the hair shaft as continuous bands, building up the cuticle somewhat like a pile of tall tumblers set one within the other, as in the hair of the intermediate bat (Fig. 19). Of these two primal types there are a multitude of intricate variations. The pelage of a very large number of mammals consists of two kinds of hair; a soft, dense, short, fine hair, called the under or furhair, and a longer, coarser, stiffer, sparser growth, which projects beyond and overlies the fur hair, termed the over or protective hair. Examination of both of these types of hair is sometimes necessary, though ordinarily the shafts of the fur hair alone furnish sufficiently conclusive identification data. In felting, particularly, both kinds of hair are usually included in the fabric, when the hair of such mammals as the cat, or of the different species of beaver, rabbits and hares, is used.

Heretofore the methods of preparation and examination of hair shafts have been too crude to afford exact

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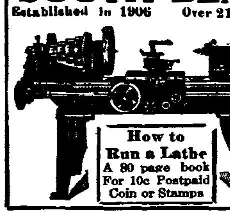

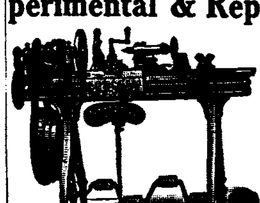

Reclaiming the No-Man's-Land of America

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This dipper is thrust down to the bottom of the ditch and given a scooping motion which fills it. The next operation is to raise the beam and by swinging it to one side bring it over the bank, when the door is unlocked and the contents discharged. By repeating this operation the bottom is excavated to such depth as desired.

Fastened to the dredging machine by means of stout ropes are the quarter boats where the workmen live. These quarter boats follow the machine from place to place as the work progresses.

Before the dredges begin operations, and after the land is surveyed, parties of workmen led by engineers go ahead clearing a right-of-way, chopping away timber and tangled undergrowth. This is perhaps the hardest work of all, as it is sometimes necessary that these pioneer axmen work in water above their waists. Sometimes, too, they must face the shotgun of an irate land-owner, who, confirmed in the habits of years, scorns modern improvements. Indeed, in more than one instance it has been necessary to wait months for the settlement of a lawsuit before work can proceed.

The cost of drainage varies from $10 to $30 an acre, spread over a period of years so as not to make the burden onerous. The cost of maintenance is nominal.

In the last ten years there has been an awakening to the opportunity that lies in the swamp lands of the South and Middle West, and a remarkable transformation is taking place. Drainage canals thousands of miles long are being dug; boisterous, misbehaving streams are being straightened and kept within their proper banks. In many places a ditch fifty feet wide is carrying the water that formerly filled a sluggish slough half a mile wide. Towns are springing up, and broad vistas of fertile fields are rapidly replacing the snake and frog infested lakes and quagmires.

San Francisco as a Fuel Oil Port

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Each of these barges is operated by one man, and special precautions are taken so as to enable the operator to handle all equipment. As a safety precaution the fuel for operating the gasoline engine is carried in a 10-gallon tank located on the deck of the barge. Two powerful electric lights are provided on deck. They are of the goose neck type, and are provided with reflectors, held in such a manner that the entire deck of the barge is flood lighted, enabling work to be carried on at night as readily as during the day.

The main oil pumps are of the tandem duplex compound type, having a capacity of about 1,500 barrels an hour. Steam is generated by boilers located in the pump room. The exhaust steam from the pumps enters a special drum where the boiler feed water is heated to a temperature of 180 degrees. A novel feature is the arrangement for supplying oil to the 110-gallon fuel-oil tank for the boilers. A 1½-inch pipe leads from the cargo tank to the 110-gallon tank, and when oil is being pumped from the cargo tanks (into storage tanks of the company located along the San Francisco water front, not when oil is being pumped aboard a steamer) the engineer opens a valve which delivers oil also directly into the 110-gallon tank, thus saving an extra pump for this purpose. It requires about 85 barrels of fuel to operate the pumps while 3,000 barrels of oil are being pumped from the cargo tanks. Another novel feature is the fact that the oil pumps are connected with the bilge by means of a large pipe, and in case the barge should spring a large leak, the water can be pumped from the bilge by the regular oil pumps and discharged overboard. There is also a special duplex pump for use in case of fire, and for washing down the deck of the barge. The deck is washed down daily during the dry season. A 150-foot fire-hose is carried on deck on a special reel. This hose is of sufficient length to reach any part of the barge.

A derrick is provided at one end of the barge for handling the 30-foot sections of hose for making connection to the pipe lines leading to shore storage tanks and for connecting up to fuel oil tanks on ships. By means of this one man is enabled to swing the heavy hose around to the side of a ship and connect it up ready for pumping.

In the living quarters there is a galley, with a kerosene stove, on which the operator cooks his food. He has a porch on each side of the living room, and can put up an awning on one side to keep out rain or sun. Numerous life preservers are also carried on the house, as well as a fog bell, which the operator rings constantly during foggy weather.

One of our pictures is rather unusual because it shows a Japanese steamer taking on fuel oil and coal at the same time. The Japanese steamers are equipped with both oil-burning and coal-burning boilers. The ships coal at both ports, but get oil only at one end of their journey. So sufficient coal is taken on at San Francisco to run until the vessel arrives at Japan, where sufficient coal is taken on to last until the vessel reaches San Francisco; but sufficient oil is taken on at San Francisco to last the oil-burning boilers for the entire trip to Japan and then returning to San Francisco.

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knowledge of the form, structure, and interrelationships of the cuticular scales of most kinds of hairs, with the exception of certain types of wools where these elements are of unusual size and prominence. And in regard to the finer hairs used in the textile industry (such as those of the camel, alpaca and angora goat), the prevailing notion has been that when animal hairs become straighter, finer, and more filamentous in form, it becomes increasingly difficult to observe the individual scales, *not* because these may not be as plain and definite as those of sheeps' wool, but due to the suppositious fact that the individual scales fuse together, until the hair shaft becomes a smooth rod-like structure, devoid of any surface sculpturings. Nothing could be farther from the truth. The differences in form and structure of the medulla and the pigment granules seem not to have been made use of heretofore, though these also furnish excellent determinative criteria.

The preparation of many of the mammal hairs for ordinary examination is not laborious. Several hair shafts are taken and washed in a solution composed of equal parts of 95 per cent alcohol and ether or chloroform, to remove any oily matter from their surfaces. They are then dried in a current of warm air from an alcohol lamp; transferred to a clean glass slide, and covered with a cover glass. Examination can now be made directly, using the 8x or 10x ocular, and the 16 mm. and 4 mm. objectives. This simple treatment answers very well for those hairs whose cuticular scales are large and prominent, such as those of the various varieties of wool. In other cases the hairs must be washed in the ether-alcohol, as before, and then dipped with fine forceps into a solution of gentian violet in 95 per cent alcohol, of a degree of color depth which it is necessary to determine empirically for different kinds of hairs. (Other stains which go readily into solution in alcohol, *e. g.* methyl blue, methyl violet, Bismark brown, and safranin, can also be used. Frequently stains which give good results with one kind of hair will be much less satisfactory with another.) Such treatment ren-

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ders visible the outlines of the individual scales of many of the finer hairs. However, even this manipulation fails with the finest hairs, and other methods devised by the writer—too lengthy for description here—must be called into service. The various treatments with caustic soda, caustic potash, and acids, hot or cold, often recommended, distort the scales, and render them valueless for accurate determinative purposes. The degree of success obtained with the microscope in the determination of scale sculpturings and other characters, often depends as much upon the intensity and colors of the light used for illumination, the position of its source, and the combinations of objectives and oculars employed as upon the previous preparation of the hair itself.

The various treatments used to render visible the cuticular scales all obscure the medulla, hence other methods must be employed to bring into prominence this element of the hair shaft structure. The simplest and most generally useful of these is to mount the hair on a slide in some one of the light oils used in histological work, such as oil of cloves, bergamont, peppermint, or cedar, etc., after having washed it, as before, in the ether-alcohol solution. With a few hairs it is sometimes satisfactory to use clear water as the mounting medium. Such methods are also useful to make clear the pigment granules of certain hairs. With others more lengthy treatments must be called into requisition, especially when the exact determination of the form of the granules, their mode of coalescence, and their relations to the component cells of the cortex, is the end in view. It is sometimes necessary to prepare transverse sections through the hair, for the purpose of more accurate observation of the pigmentation of the shaft, as well as for the determination of the contour of the medulla, and the form and placentation of its component cells and chambers. This is one of the most precise and tedious operations in trichologic investigation. Fig. 20 shows several shafts of human hair sectioned in this way.

For the various measurements made of theh air shaft or its parts, the ocular micrometer, with a moveable scale, is the most satisfactory. Since, in any given tuft of hairs, there are considerable variations in the size of the shafts or their structures, the average of several measurements, made at several definite points along the shaft, should be taken.

The captions of our group of drawings enumerate those species of mammals whose hair is the most extensively used in the textile industry, together with the number of the figure wherein is shown the microscopic appearance of the fur or under hair. The average diameter of the shafts of this hair, in micra, is in each case attached. In each figure two hair shafts are depicted; one treated to show the cuticular scales, the other to show the medulla. The various shafts are drawn as nearly to scale as is practicable in representing objects of such widely varying dimensions, so that a glance at the figures will afford some graphic appreciation of the relative sizes of the hairs. The figures of the hair of the horse (Fig. 10) and of the Virginia deer (Fig. 11) have been reduced in scale, however, and the figure of the hair of the intermediate bat (Fig. 19) increased.

Speaking of Tall Chimneys

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the force of a hurricane. The maximum range of oscillation was 7.7 inches. As these oscillations were executed in 2.55 seconds, it follows that the maximum acceleration during the movement was 22.5 inches per second, which exceeds that of a semi-destructive earthquake. All this agrees, it would seem, with the excellent

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