Hair and Fiber Analysis

Definition: Threads and threadlike textile materials of natural or human-made origins.
Significance: Fibers and filaments are often among the trace evidence samples collected at crime scenes and from crime victims and potential suspects. Because fibers and filaments are easily transferred from objects to persons, from persons to objects, and from persons to persons, the analysis of such materials found in relation to crimes can provide investigators with important information.

The forensic analysis of fibers and filaments has been practiced for more than a century. Forensic scientists define a fiber as the smallest unit of a textile material that has a large length-to-diameter ratio. Based on length, fibers may be classified as either staple fibers or filaments. “Filament” is the term used to refer to a fiber with indefinite or extreme length; many synthetic fibers and some wool fibers are classified as filaments.

Fibers and filaments can be left at crime scenes in a variety of ways. In sexual assault and homicide cases, for example, cross-transfer of fibers often occurs through personal contact between suspect and victim. In a burglary, fibers from the perpetrator's clothes may be caught on window screens, furniture, or broken glass. When fibers recovered from a crime scene are analyzed, they can often place particular persons at the scene and serve to corroborate other evidence gathered during the course of the investigation.

Plant Fiber Identification

Forensic investigators collect fibers at crime scenes using tape, forceps, and vacuums. The sources of the fibers collected may be such items as clothing, blankets, carpeting, wigs, and furniture upholstery. The fibers are then separated in the laboratory into natural, manufactured, and mixed types.

Natural fibers are those that have their origins in plants (such as cotton), animals (such as wool), or minerals (such as asbestos). During the analysis of natural fibers, the scientist seeks to distinguish the materials' plant, animal, or mineral origins. In general, microscopic examination is conducted; the scientist looks at both a cross section of each fiber and its outer length. When further analysis is needed to determine a fiber's origin and identity, burning and solubility tests are employed. Sometimes, color tests using special stains are also conducted. These color tests require the stripping of dyes and the use of differential stains; the instruments used to analyze the results are more sophisticated than those needed for other fiber tests.

Plant fibers are subdivided into three broad categories, depending on which part of the plant is the source of the fiber. Seed fibers include cotton, kapok, and coir; stem fibers, also called bast fibers, include flex and hemp; and leaf fibers include manila and sisal. Cotton fibers are by far the most common in the textile industry. Under a light microscope, cotton fibers look like twisted, flattened tubes, very irregular in appearance; these fibers remain bright in appearance in all orientations. Mercerized cotton appears somewhat featureless and less twisted, but the irregular form remains.

Less common plant fibers include flax (linen), ramie, sisal, jute, hemp, kapok, and coir. Each of these fibers has unique characteristics that are visible under the microscope; variations in size, directions of twist, ridges and striations, and other markings allow forensic scientists to identify individual types of fibers.

Animal Fiber Identification

Animal fibers, which are made up primarily of proteins, can be divided into three subgroups on the basis of protein composition and utilization: silk, wool, and hair fibers. Silk contains primarily fibroin and thus dissolves when placed in concentrated hydrochloric acid. When subjected to flame, silk fibers emit an odor similar to that of burning hair. Raw silk contains sericin, a globular protein, which is usually removed during the process through which silk yarn is produced for use in the textile industry. Like different kinds of plant fibers, various types of silk have different appearances under the microscope, enabling forensic scientists to distinguish among them.

The principal protein in wool is keratin. Raw wool typically contains substantial amounts of impurities, including soil, grease, sweat, and other organic matter. Clean wool, or pure keratin, is obtained through a scouring process by which raw wool is washed and the impurities removed. The most common wool fibers originate from sheep; other wool fibers come from goats (such as cashmere and mohair) and from camels. Each of these kinds of fibers displays unique characteristics of texture, color, and size under the microscope.

Human-Made Fibers

In the United States, more than 50 percent of the fibers used in fabrics are synthetic materials. Some human-made fibers are derived from natural materials, such as cotton and wood, whereas others originate exclusively from synthetic materials. In the manufacture of synthetic fibers, liquefied fiber-forming materials (natural or synthetic or a combination of the two) are forced through holes into the air so that they form threads. Whereas natural fibers viewed under the microscope often display rough external surfaces, human-made fibers appear smooth and more uniform, and some may have long extrusion lines on the surface.

Manufactured artificial fibers are traditionally made from cellulose of plant origin, whereas synthetic fibers are made exclusively from synthesized polymers. Widely used artificial fibers include viscose rayon and cellulose acetate. Viscose rayon is a cellulosic fiber regenerated through manufacturing processes to imitate the feel and texture of silk, wool, or cotton. Rayon fibers are naturally very bright and can be dyed easily; under the microscope, they display lengthwise striations and an indented circular cross section. Cellulose acetate is the acetate ester of cellulose made from cotton or tree pulp. The fiber has good draping qualities, dries fast, and resists shrinking, wrinkling, and mildew. Acetate fibers have a luxurious feel and appearance and range widely in color and luster.

The most common synthetic fibers are nylon and polyester. "Nylon" is a general term for a family of synthetic polymers designed originally as a synthetic replacement for silk. Nylon fibers are often used in fabrics, carpets, ropes, and even the strings of musical instruments. The cross sections of nylon fibers may be manufacturer-specific. Many forms of polyesters are in existence, including plant-based cutin and synthetic polyesters such as polycarbonate and polybutyrate. The term "polyester" is most commonly used to refer to polyethylene terephthalate. Polyester has been the most widely produced synthetic fiber since 1970.

Value of Fiber Evidence

The value of fiber evidence to criminal investigations varies widely, depending on the numbers, locations, and characteristics of the fibers recovered. Because of the diversity and considerable variations in fibers and filaments, they are considered "class" evidence—that is, identification using such evidence is based on probability, not certainty. As class evidence, fiber evidence alone is not enough for conviction. Identification of a suspect through such evidence must be corroborated by other evidence to present a strong prosecution case.

The amount of a particular fiber produced and included in end products determines the degree of rarity of that fiber and, often, its usefulness in a forensic investigation. The rarer the fiber, the higher the value if a match occurs between a crime scene sample and a sample taken from a suspect. The shape of a fiber can determine the value placed on that fiber as well, because the cross section of a fiber can be manufacturer-specific. Some cross sections are more common than others, and some shapes may be produced only in small quantities or for short periods of time. Unique or rare cross sections discovered in analysis can have increased significance for fiber association.

Other factors that affect the value of fiber evidence include color, the number of fibers collected, and the specific locations in which fibers are recovered. How stains are applied and absorbed along the length of a fiber provides an important characteristic for comparison during examination. The greater the number of fibers found on the victim or at the crime scene that match the suspect's clothing, the stronger the argument that physical contact occurred. The recovery of fibers from specific locations on a victim's body may be a significant indicator of the nature of a crime.