

Fiber Analysis Notes

Right this minute, countless fibers are on and around you. Some of them originated from your home and some were passed to you when you hugged your parents or bumped into a classmate on the way to class.

Clothing, carpet, car mats, bedding, towels, and thousands of other things that you use every day are composed of various fabrics. Because they're so common and come in such a wide variety of types, fibers from these fabrics are an important type of trace evidence. Like hair, they're easily shed, transferred, and transported. They stick to skin and clothing and become entangled in hair. Criminalists may collect fibers from the victim's or the suspect's body, hair, clothing, home, or car, or from the crime scene. The crime lab may use these fibers to try to identify the manufacturer or the source of a particular fiber or match one fiber with another.

Classifying Fibers

A **fiber** is any threadlike element of a material – the threads in your shirt or tiny pieces twisted together in your carpet.

The rarity or commonness of the fiber types found at a crime scene or on a victim or suspect affects their probative value. Cotton fibers are by far the most commonly used plant fibers in textile production. The type of cotton, the fibers' length, and the degree of twist contribute to the diversity found in cotton fibers. Processing techniques, such as mercerization, and color applications also influence the value of cotton fiber identifications. The presence of other less common plant fibers at a crime scene or on the clothing of a victim or suspect increases its significance.

Fibers fall into three basic categories:

Natural fibers come from various animals, plants, and minerals. Examiners can often easily identify and compare these fibers by microscopic inspection alone. Animal hair that is woven into fabric or used to manufacture clothing and other household items is considered natural fiber. Other examples are wool, mohair, cashmere, and silk. Plant fibers include cotton, hemp, flax, and jute.

By far, the most commonly used natural fiber is cotton. When examined under a microscope, it has an easily recognizable twisted-ribbon pattern. Undyed white cotton is so common that it's of little evidentiary value. Natural fibers derived from minerals include such materials as asbestos.

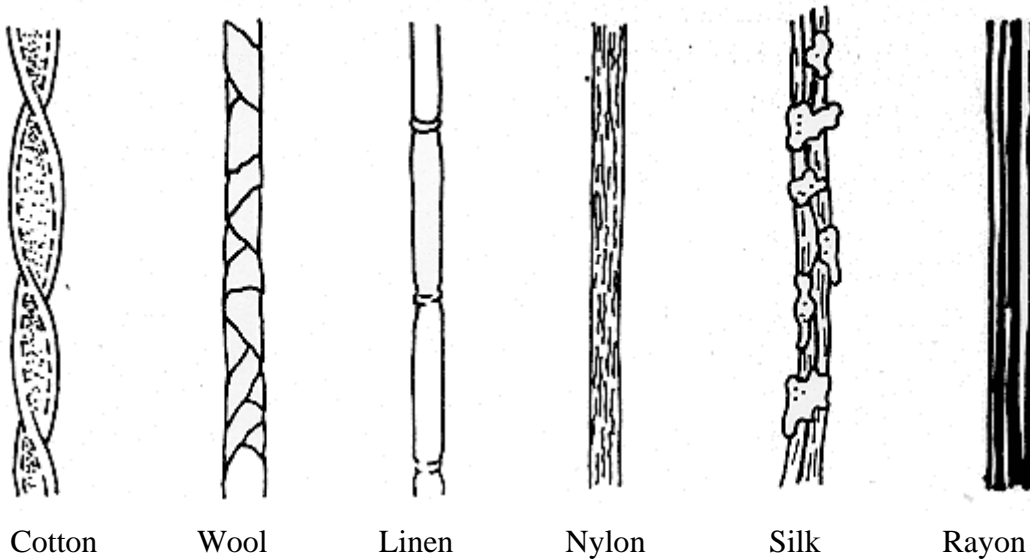
The most common animal fiber used in textile production is wool originating from sheep. The fineness or coarseness of woolen fibers often dictates the end use of wool. The finer woolen fibers are used in the production of clothing, whereas the coarser fibers are found in carpet. The diameter and the degree of scale protrusion of the fibers are other important characteristics. Woolen fibers from other animals may also be found, including camel, alpaca, cashmere, and mohair. The identification of less common animal hairs, fibers, or both at a crime scene or on the clothing of a suspect or victim would have increased significance.

Manufactured, or regenerated, fibers are fabrics like rayon, acetate, and triacetate. To make them, raw cotton or wood pulp is dissolved, and cellulose is extracted. The cellulose is then regenerated into fibers.

Synthetic fibers come from *polymers*, which are substances made up of a series of *monomers* (single molecules) strung together to make larger molecules that can be thousands of monomers long. Nylon and polyester are synthetic fibers.

Over half of all fibers used in the production of textile materials are manufactured. Some manufactured fibers originate from natural materials such as cotton or wood, whereas others originate from synthetic materials. All nonnaturally occurring fibers are manufactured, but not all manufactured fibers are synthetic (e.g., rayon). Certain types of manufactured fibers are more common than others. Polyester and nylon fibers are the most commonly encountered manufactured fibers, followed by rayons, acetates, and acrylics. There are also many other less commonly manufactured fibers. The amount of production, the end use, the cross-sectional shape, microscopic characteristics, and other traits of the fiber help to influence the degree of rarity of a particular fiber type.

Fabrics



Wool - Fibers from animal coats: Sheep, goats, rabbits, alpacas, llama...

Cotton - Fibers from the cotton plant's seed pod

Silk - Fibers from the cocoon of the silkworm

Linen - Linen is from flax, a bast fiber taken from the stalk of the plant

Hemp, Ramie, and Jute - All of these are similar

Wool

WOOL fabric brings to mind cozy warmth. Some wools are scratchy giving some people the idea that they are "allergic" to wool. Although wool fiber comes from a variety of animal coats, not all wools are scratchy but rather extremely soft. The wool fibers have crimps or curls which create pockets and gives the wool a spongy feel and creates insulation for the wearer. The outside surface of the fiber consists of a series of serrated scales which overlap each other much like the scales of a fish. Wool is the only fiber with such serrations which make it possible for the fibers to cling together and produce felt. The same serrations will also cling together tightly when wool is improperly washed and shrinks! Wool will not only return to its original position after being stretched or creased, it will absorb up to 30% of its weight in moisture without feeling damp. Its unique properties allow shaping and tailoring, making the wool the most popular fabric for tailoring fine garments. Wool is also dirt resistant, flame resistant, and, in many weaves, resists wear and tearing.

Basically, there are two different processes used in wool production. Woolen fabrics have a soft feel and fuzzy surface, very little shine or sheen, will not hold a crease, and are heavier and bulkier than worsteds. Blankets, scarves, coating, and some fabrics are considered woolens. Worsted wool is smoother than woolen, takes shine more easily, does not sag, holds a crease well, is lighter and less bulky, and wears longer than woolen. Worsted wool's require a greater number of processes, during which fibers are arranged parallel to each other. The smoother, harder-surface worsted yarns produce smoother fabrics with a minimum of fuzziness and nap. Fine worsted wool is even seen in clothing for athletics such as tennis. No, they are not hotter than polyester but actually cooler, as the weave of the fabric allows wool to absorb perspiration and the fabric "breathes," unlike polyester.

WOOL SPECIALTY FIBERS, although still classified as wool, are further classified by the animal the fiber comes from.

Alpaca fleece is very rich and silky with considerable luster. It comes from the Alpaca.

Mohair is from the angora goat and is highly resilient and strong. Mohair's luster, not softness, determines its value. Mohair is used in home decorating fabrics as well as garment fabrics including tropical worsteds.

Angora wool is from the angora rabbit. This soft fiber is used in sweaters, mittens and baby clothes.

Camel hair is from the extremely soft and fine fur from the undercoat of the camel. Camel's hair can be used alone but is most often combined with fine wool for overcoating, topcoating, sportswear and sports hosiery. Because of the beauty of the color, fabrics containing camel's hair are usually left in the natural camel color or dyed a darker brown. Light weight and soft, it is said that a 22 oz. camel fabric is as warm as a 32 oz. woolen fabric.

Cashmere is from the Kasmir goat down. Separation of the soft fibers from the long, coarse hair is tedious and difficult, contributing to the expense of the fabric. The soft hair is woven or knitted into fine garments and can also be blended with silk, cotton, or wool.

Vicuna is the softest coat cloth in the world. The amount of coarse hair to be separated from the soft fibers is negligible and yields the finest animal fiber in the world. Vicuna is a member of the Llama family and is small and wild. Since it is generally killed to obtain the fleece, it is protected by rigorous conservation measures. This fiber is rare and very expensive, costing several hundred dollars per yard.

Cotton

COTTON, cool, soft, comfortable, the principal clothing fiber of the world. Its production is one of the major factors in world prosperity and economic stability. Cotton "breathes". What would we do without cotton? Since cotton wrinkles, polyester was added to give it wash and wear properties for a busy world. In recent times, the consumer determined that polyester, although easier to care for, took away the cool from cotton and also added a "pilling" effect to cotton/polyester blends. Consumers now often request "100% Cotton". Permanent finishes also added to the all cotton fabric gave a wash and wear property to cotton. cotton. The cotton fiber is from the cotton plant's seed pod The fiber is hollow in the center and, under a microscope looks like a twisted ribbon. "Absorbent" cotton will retain 24-27 times its own weight in water and is stronger when wet than dry. This fiber absorbs and releases perspiration quickly, thus allowing the fabric to "breathe". Cotton can stand high temperatures and takes dyes easily. Chlorine bleach can be used to restore white garments to a clear white but this bleach may

yellow chemically finished cottons or remove color in dyed cottons. Boiling and sterilizing temperatures can also be used on cotton without disintegration. Cotton can also be ironed at relatively high temperatures, stands up to abrasion and wears well.

Mercerized cotton is treated to permanently straighten the cotton fibers which then becomes a smooth, rod-like fiber that is uniform in appearance with a high luster. Cotton is often blended with other fibers such as polyester, linen, wool, to "blend" the best properties of each fiber.

Muslin is a sheer to coarse plain woven cotton fabric. Muslin comes in "natural" color or is dyed.

Organdy is a very thin, transparent cotton with a crisp finish.

Outing flannel is a soft, twill or plain weave fabric napped on both sides. Used for baby clothes, diapers, and sleepwear.

Oxford is shirting fabric with a lustrous, soft finish. It is characterized with narrow stripes and can be woven in plain or basket weave. Also a term used for wool fabric that has black and white fibers.

Percalé is a light weight, closely woven, sturdy fabric that can be found printed in dark colors.

Pima Cotton, from Egyptian cotton, is an excellent quality cotton fabric.

Polished Cotton is either a satin weave cotton or a plain weave cotton that is finished chemically to appear shiny.

Poplin is a plain weave fabric with a cross-wise rib.

Sailcloth is a very strong, heavy canvas or duck made in plain weave.

Sateen is a satin weave cotton fabric.

Seersucker is a lightweight cotton fabric crinkled into lengthwise stripes.

Swiss is a sheer, very fine cotton that can be plain or decorated with dots or other designs.

Terry Cloth is a looped pile fabric that is either woven or knitted. Very absorbent and used for towels, etc. French terry cloth is looped on one side and sheared pile on the other.

Velveteen is an all cotton pile fabric with short pile resembling velvet.

Whipcord is a strong fabric with a diagonal round cords that can also be produced in wool.

Silk

SILK, the fabric that makes its own statement. Say "silk" to someone and what do they visualize? No other fabric generates quite the same reaction. For centuries silk has had a reputation as a luxurious and sensuous fabric, one associated with wealth and success. Silk is one of the oldest textile fibers known to man. It has been used by the Chinese since the 27th century BC. Silk is mentioned by Aristotle and became a valuable commodity both in Greece and Rome. During the Roman Empire, silk was sold for its weight in gold.

Today, silk is yet another word for elegance, and silk garments are prized for their versatility, wearability and comfort. Silk, or soie in French, is the strongest natural fiber. A steel filament of the same diameter as silk will break before a filament of silk. Silk absorbs moisture, which makes it cool in the summer and warm in the winter. Because of its high absorbency, it is easily dyed in many deep colors. Silk retains its shape, drapes well, caresses the figure, and shimmers with a luster all its own.

Contemporary silk garments range from evening wear to sports wear. A silk suit can go to the office and, with a change of accessories and a blouse, transform into an elegant dinner ensemble. Silk garments can be worn for all seasons.

Silk -- elegant, versatile and washable. In the past, owning a silk garment meant not only the initial price of the garment but also the cost of dry cleaning. All silk is washable. Silk is a natural protein fiber, like human hair, taken from the cocoon of the silkworm. The natural glue, sericin, secreted by silkworms and not totally removed during manufacturing of the silk, is a natural sizing which is brought out when washing in warm water. Most silk fabrics can be hand washed. Technically, silk does not shrink like other fibers. If the fabric is not tightly woven, washing a silk will tighten up the weave.... thus, lighter weights of silk (say a crepe de chine of 14 mm) can be improved by washing as it will tighten up the weave. A tightly woven silk will not "shrink" or will "shrink" a lot less. Silk garments, however, can shrink if the fabric has not been washed prior to garment construction. When washing silk, do not wring but roll in a towel. Silk dries quickly but should not be put in an automatic dryer unless the fabric is dried in an automatic dryer prior to garment construction. A good shampoo works well on silk. It will remove oil and revitalize your silk. Do not use an alkaline shampoo or one which contains ingredients such as wax, petroleum, or their derivatives, as these products will leave a residue on your silk and may cause "oil" spots. If static or clinging is a problem with your silks, a good hair conditioner (see above cautions) may be used in the rinse water.

Silk may yellow and fade with the use of a high iron setting. Press cloths and a steam iron are recommended. Silk is also weakened by sunlight and perspiration.

Noil is sportier in appearance and created by short fibers, often from the innermost part of the cocoon. Has the look of hopsack but much softer.

Organza is similar to cotton organdy except it is made with silk and is transparent.

Peau de Soie is a stout, soft silk with fine cross ribs. Looks slightly corded. Also called paduasoy.

Pongee is a plain woven, thin, naturally tan fabric that has a rough weave effect.

Poult de siue is sometimes called faille taffeta. It has heavy cross ribs.

Silk Shantung is a dupionni type of silk that comes from the Shantung Prov. of China.

Silk Broadcloth is a plain weave silk in various weights; crisper than china silk. Often used in shirting.

Silk linen has a nubby yarn in a plain weave. Weights range from light to heavy. It is different from Dupion in that the nubby runs both lengthwise and crosswise. The look of linen with the characteristics of linen.

Silk satin is a satin weave with a plain back.

Tussah silk (tussah means wild) is a plain weave silk fabric from "wild" silk worms. It has irregular thick and thin yarns creating uneven surface and color. Wild silkworms feed on leaves other than mulberry leaves. Tussah silk is similar to shantung, with silk from the wild. Color is often uneven; usually referred to as "raw" silk.

Silk is also available in other weaves such as velvet and corduroy.

Linen

LINEN, elegant, beautiful, durable, the refined luxury fabric. Linen is the strongest of the vegetable fibers and has 2 to 3 times the strength of cotton. Linen table cloths and napkins have been handed down generation to generation. Not only is the linen fiber strong, it is smooth, making the finished fabric lint free. Fine china, silver and candles are enhanced by the luster of linen which only gets softer and finer the more it is washed.

Linen is from flax, a bast fiber taken from the stalk of the plant. The luster is from the natural wax content. Creamy white to light tan, this fiber can be easily dyed and the color does not fade when washed. Linen does wrinkle easily but also presses easily. Linen, like cotton, can also be boiled without damaging the fiber.

Highly absorbent and a good conductor of heat, this fabric is cool in garments. However, constant creasing in the same place in sharp folds will tend to break the linen threads. This wear can show up in collars, hems, and any area that is iron creased during the laundering. Linen has poor elasticity and does not spring back readily.

Damask, a jacquard weave, is a reversible rich weave, patterned in satin or plain weave.

Venise is a very fine damask table linen consisting of large floral patterns.

Hemp, Ramie, Jute

HEMP is currently being used by designers in clothing. When thinking of hemp, the illegal plant, marijuana comes to mind. No, hemp fabric does not contain the narcotic chemical that, when smoked produces the "high" that smoking marijuana produces. Marijuana is from the dried flowers and leaves of the Cannabis Sativa plant. Hemp fabric is made from the stems of the plant. The stems are processed to dissolve the gum or pectin and separate the fibers which are then processed again and woven into yarns and fabric. The finest hemp for fabric is produced in Italy. Hemp fabric is like linen in both hand and appearance. Hemp fabric withstands water better than any other textile product. It wrinkles easily and should not be creased excessively to avoid wear and breakage of the fibers.

RAMIE is also similar to linen and is a bast of plant fiber. It is natural white in color, has a high luster and an unusual resistance to bacteria and molds. Used in fabrics, and often mistaken for linen, it is extremely absorbent and dries quickly. Ramie has excellent abrasion resistance and has been tested to be three to five times stronger than cotton and twice as strong as flax. It is an inexpensive fiber from an East Asian plant and can be spun or woven into a fabric.

JUTE is a glossy fiber from a plant. It is seen most often in sacks, rope, twine, and as backing on carpeting.

Common Rope Materials

The three most common rope materials are nylon, polyester, and polypropylene. Polyethylene is sometimes encountered. Some ropes are made of combinations of several of these materials.

Nylon is generally the strongest of these common materials when dry. However, some nylon ropes lose as much as 20% of their strength when wet. Two forms of nylon are used in ropes; nylon 6 and nylon 6.6. The properties of these fibers, and the ropes made from them, are not significantly different, except nylon 6 has a lower melt point temperature.

Polyester ropes are almost as strong as nylon when dry. Polyester retains its strength when wet, and thus polyester ropes are generally stronger than nylon ropes when wet.

Polypropylene is probably the most common material found in ropes used in the marine field. One reason is that it is lighter than water, and thus it floats.

Polyethylene is uncommon in large ropes. It is used in water-ski ropes and other small ropes used for utilitarian purposes. It is used extensively in the fishing industry.

Collecting Fibers

Time is critical when collecting fiber evidence because studies show that fibers clinging to the clothing of a victim or suspect are lost quickly. After four hours, 80 percent of them may have fallen away, and after 24 hours, 95 percent may be gone. A search for trace evidence on the clothing of the victim and any suspects therefore needs to take place as soon as possible. Fibers can be lifted from clothing with tape or by vacuuming.

Comparing Fibers

In the lab, a fiber analyst first examines unknown fibers under a stereomicroscope, assessing their diameters, shapes, colors, shininess, and curls and crimps, and then looking for any attached debris. When matching two fibers, the analyst uses a comparison microscope so that two or more fibers can be compared side-by-side.

Other tools that help the investigator dig deeper into the fiber's physical and chemical characteristics are

Birefringence: When light passes through some synthetic fibers, it's refracted twice and emerges as two different wavelengths of polarized light, each with its own refractive characteristics. A comparison of the birefringence of two fibers is useful for identification and comparison.

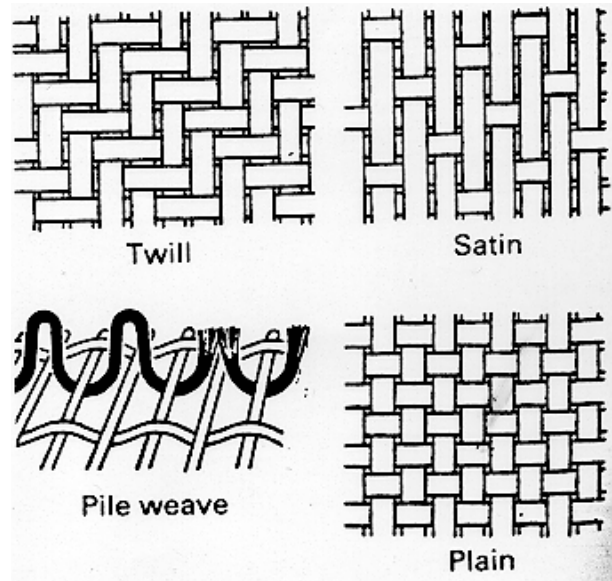
Microspectrophotometry: This process helps the examiner determine a fiber's true color without the problem of observer bias.

Polarized light: This tool estimates the reflective index (the amount and angle of light reflected by an object or substance) of the fiber and helps determine its makeup.

Refractive index: The refractive index is measured by directing a narrow light beam at a fiber and calculating the degree to which light is bent as it passes through. This index varies from fiber to fiber.

Scanning electron microscope: Whenever a fiber or piece of fabric is damaged, the fiber analyst can use an SEM to examine fine structural and surface details that can reveal exactly how the damage occurred.

If a sample of fabric is available a forensic scientist might look at the construction of the fabric to help trace it back to a particular type of clothing or particular weave patterns in the fabric might help in the search for evidence. Some common weaving patterns are shown at the right.



Breaking Down the Fiber

Two commonly used procedures – the combination of SEM with dispersive X-ray spectrometer (SEM/EDS) and the combination of gas chromatography with a mass spectrometry (GS/MS) – can yield the chemical composition of the fiber and of any pigments or treatments that have been added to it during the manufacturing process or as a later alteration. In fact, GC/MS can separate and identify each chemical found in the fiber or in the various applied treatments. For example, the presence of tin and bromide can indicate treatment with a fire retardant. Titanium oxide is found in many delustering products, substances that lessen a fiber's luster or shine.

These chemical determinations can point to the manufacturer of the fiber or serve to more strongly match one fiber with another. After analyzing the physical and chemical properties of known and unknown fibers, the criminalist may be able to say that the two very likely came from the same source. If, on the other hand, the fibers differ in any of their characteristics, the criminalist concludes that they didn't share a common source.