

CHAPTER 4

A Study of Fibers and Textiles

A THREAD OF EVIDENCE

In the 1980s, a string of murders left the African American youth of Atlanta in a state of fear. For 11 months, someone was kidnapping and disposing of victims in and around Atlanta's poor neighborhoods. The victims were asphyxiated either by rope or smothering, and the bodies were disposed of in dumpsters or wooded areas. Although the police had no suspects, they were gathering a collection of unusually shaped fibers from the victims. When the fiber evidence hit the news, the bodies began to turn up in the river.

One night, two police officers were staking out a bridge over the Chattahoochee River, where many victims had been found, when a white station wagon stopped on the bridge. The car was seen driving off after something had been tossed over the bridge. The officers followed and stopped the car, and the driver, 33-year-old Wayne Williams, was arrested on suspicion of murder.

The problem faced by the police was a lack of a pattern and motive. There seemed to be no reason for the killing spree. Williams was an unsuccessful music producer and a pathological liar, but to many people, he did not seem like a killer. However, the prosecution's fiber evidence seemed to suggest otherwise.



©AP Photo/Charles Kelly

Wayne Williams.

Fibers of an unusual type that matched the carpeting in Williams's house were found on many of the victims. What the court did not hear was that no fiber evidence from the victims was found in Williams's home, other than a single red cotton fiber. Could Williams be guilty and have removed every trace of his crimes, or was he innocent? The jury chose guilty. Of the 29 murders, Williams was convicted of two and sentenced to life imprisonment. The life sentence rested entirely on his choice of carpeting.

Did they get the right man? Some do not think so. After all, there were no witnesses to the crime, no motive, and no confession.

OBJECTIVES

By the end of this chapter you will be able to:

- ✓ Identify and describe common weave patterns of textile samples.
- ✓ Compare and contrast various types of fibers through physical and chemical analysis.
- ✓ Describe principal characteristics of common fibers used in their identification.
- ✓ Apply forensic science techniques to analyze fibers.



VOCABULARY

amorphous without a defined shape; fibers composed of a loose arrangement of polymers that are soft, elastic, and absorbing (for example, cotton)

crystalline regularly shaped; fibers composed of polymers packed side by side, which make it stiff and strong (for example, flax)

direct transfer the passing of evidence, such as a fiber, from victim to suspect or vice versa

fiber the smallest indivisible unit of a textile, it must be at least 100 times longer than wide

mineral fiber a collection of mineral crystals formed into a recognizable pattern

monomer a small molecule that may bond to other monomers to become a polymer

natural fiber a fiber produced naturally and harvested from animal, plant, or mineral sources

polymer a substance composed of long chains of repeating units

synthetic fiber a fiber made from a man-made substance such as plastic

secondary transfer the transfer of evidence such as a fiber from a source (for example, a carpet) to a person (suspect), and then to another person (victim)

textile a flexible, flat material made by interlacing yarns (or "threads")

yarn fibers that have been spun together

INTRODUCTION

Fibers are used in forensic science to create a link between crime and suspect (Figure 4-1). For example, a thief may own a jacket made of a material that happens to match the type of fiber found at the crime scene. It does not mean he was there, but a jacket like his was. If a jacket fiber, sock fiber,

and shirt fiber all from items the thief owns are found at the crime scene, then the chances that the suspect was actually there are high or increased.

If we wear clothes, we shed fibers. As we walk on carpet, sit on couches, or pull on a sweater, fibers will fall off or be picked up. Check your socks; if you have carpets or pets, you will likely have many fibers from home on you right now. The forensic scientist looks for these small fibers that betray where a suspect has been and with whom he or she has been in contact.

Unlike fingerprints and DNA evidence, fibers are not specific to a single person. Criminals may be aware of police methods and may wear gloves to prevent leaving evidence at the scene of a crime. However, very small fibers shed from most textiles easily go unnoticed, and can therefore provide a very important source of evidence for police.

Fibers are a form of trace evidence. They may originate from carpets, clothing, linens, furniture, insulation, or rope. These fibers may be transferred directly from victim to suspect or suspect to victim. This is called

direct transfer. If a victim has fibers on his person that he picked up and then transferred to a suspect, this is called **secondary transfer**. Secondary transfer might also occur when fibers are transferred from the original source to a suspect and then to a victim. For example, if a carpet fiber were transferred from the clothing of a victim to his attacker, that would be considered secondary transfer. The carpet fiber went first to the clothing of the victim and then, secondarily, to the clothing of his attacker.

Early collection of fibers in an investigation is critical. Within 24 hours, an estimated 95 percent of all fibers may have fallen from a victim or been lost from a crime scene. Thorough examination of the crime scene and the victim's body should be made for fiber evidence. Only fibers you would not expect to find are investigated. If pink fibers were found on the victim's clothes and the victim lived in a house with wall-to-wall pink carpeting, the forensic scientist would not examine these.

HOW FORENSIC SCIENTISTS USE FIBERS

Evidence of any kind must be evaluated, and this is especially important for fibers because they are so plentiful in the environment. The value of fiber evidence in a crime investigation depends on its potential uniqueness. For instance, a white cotton fiber will have less value than an angora fiber, because cotton is so common. A forensic scientist will ask questions about the following:

Figure 4-1. Fiber evidence is used in criminal cases because it shows links between suspects and victims.



©AP Photo/Joe McLaughlin



Police no longer cover dead bodies with cotton sheets because the cotton fiber sheeting may contaminate other fiber evidence on the victim.

- *Type of fiber.* What is the composition of the fiber? How common or rare? What suspects or victims or part of the crime scene had this type of fiber on them?
- *Fiber color.* Do the fibers from the suspect's clothes match the color found in the victim's house? Is the type of dye the same?
- *Number of fibers found.* How many fibers were found—one or hundreds? More fibers suggest possible violence or a longer period of contact.
- *Where the fiber was found.* How close can you place the suspect to the scene of the crime—in the house, or close to a victim's body?
- *Textile the fiber originated from.* Are these carpet fibers, or upholstery from a car?
- *Multiple fiber transfers.* Is there only one type of fiber transferred at the crime scene? Or are there fibers from numerous sources from carpets and clothes and bedding? More sources suggest longer contact or possible violence.
- *Type of crime committed.* Was the crime violent, a break-and-enter, a kidnapping? Each type of crime has an expected pattern of contact between suspect, victim, and crime scene that will be reflected in the transfer of fibers.
- *Time between crime and discovery of fiber.* How long ago did the transfer take place—an hour, a day, a week? Unless the fiber location is undisturbed (such as a bagged jacket or locked room), the value of found fiber is greatly reduced with the passage of time because fibers will be expected to fall off, or fibers not related to the crime can be picked up.

SAMPLING AND TESTING

Fiber evidence is gathered with special vacuums, sticky tape, and forceps. It is important to be very accurate in recording where the fibers are found. Inaccurate or incomplete recording may cause evidence to be inadmissible in court.

Often, the forensic scientist will obtain small amounts of fibers from a crime scene, perhaps even just a single fiber. The first task is to identify the type of fiber and its characteristics (such as color and shape) (Figure 4-2). Then the investigator attempts to match it to fibers from a suspect source, such as a car or home. When you have only one fiber as evidence, you cannot do tests that damage or alter the fiber in any way. Two methods that can analyze fibers without damaging them are polarizing light microscopy and infrared spectroscopy.

Polarizing light microscopy uses a microscope that has a special filter in it that allows the scientist to look at the fiber using specific light wavelengths. How the fiber appears can tell the scientist the type of fiber. Natural fibers, such as wool or cotton, require only an ordinary microscope to view characteristic shapes and markings. Infrared spectroscopy emits a beam that bounces off the material and returns to

Figure 4-2. Collecting fiber evidence.



Courtesy, Dr. Vaughn Bryant

Figure 4-3. An infrared spectrometer is used to identify unknown fibers.



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the instrument (Figure 4-3). How the beam of light has changed reveals something of the chemical structure of the fiber, making it easy to tell the difference between fibers that look very much alike.



If large quantities of fibers are found, some of the fibers may be subjected to simple, but destructive, testing—burning them in a flame or dissolving in various liquids. In the lab activities, you will have an opportunity to examine and compare fibers using a microscope. You will also perform burn testing to help identify fibers. Ultimately, you are asked to test your ability to solve a crime by comparing fibers found on different suspects with a fiber found at the crime scene.

Digging Deeper

with Forensic Science e-Collection

Forensic scientists can solve crimes because fibers adhere to other surfaces, such as a suspect's car seats or a victim's clothes. They also stick to hair. In fact, the nature of violent crime may mean that fibers found in a victim's hair are the only fibers recovered. Read the following articles from the Gale Forensic Sciences eCollection. You can find the Gale Forensic Science eCollection on school.cengage.com/forensicscience. Use the information in the articles to make a table that compares the fiber evidence found on clothes to the fiber evidence found in hair.

M.T. Salter and R. Cook. "Transfer of fibers to head hair, their persistence and retrieval." *Forensic Science International* 81.2-3 (August 15, 1996): pp. 211–221.

R. Cook, M. T. Webb-Salter, and L. Marshall. "The significance of fibers found in head hair." *Forensic Science International* 87.2 (June 6, 1997): pp. 155–160.



FIBER AND TEXTILE EVIDENCE

The most common form of fiber transfer to be encountered at a crime scene is shedding of a textile. **Textiles** are things like clothing, carpets, and upholstery. Many textiles are constructed by weaving, or intertwining, together **yarns**. Yarns in turn are made up of fibers that have been “spun” together.

FIBER CLASSIFICATION

Fibers are classified as either natural fibers or synthetic fibers. It is important for a forensic scientist to be able to distinguish between different kinds of fibers because this can reveal critical information about the suspect and his or her environment.

Natural Fibers

Natural fibers come from animals, plants, and minerals that are mined from the ground.

Animal fibers Animals provide fibers from three sources: hair, fur, and webbing. All animal fibers are made of proteins. They are used in clothing, carpets, decorative hangings such as curtains, and bedding.

Fur is a good donor of fibers, but it is not a textile. Rather, an animal such as a beaver or fox is trapped, and the skin removed and treated. This results in a flexible skin that retains the fur. Fur is used almost exclusively for coats and gloves.

Hair fibers are the most popular of animal fibers. Animal hair is brushed out of the animal's coat, shed naturally and collected, or clipped. The most common animal hair used in textiles is wool from sheep (Figure 4-4), but there is also cashmere and mohair from goats, angora from rabbits, as well as hair from members of the camel family—alpacas, llamas, and camels. Hair fibers are used for articles of clothing, bedding, heavy coats, carpets, bags, and furniture upholstery. When animal hair fibers are made into textiles, they are often loosely spun to feel more comfortable, making textiles that shed fibers easily.

Silk, another natural fiber, is collected from the cocoons of the caterpillar *Bombyx mori*. The caterpillars are reared in captivity, and each cocoon must be carefully unwound by hand. The shimmering appearance of silk is caused by the triangular structure of the fiber, which scatters light as it passes through, just like a prism. Fabrics made from silk are commonly used in clothing and some bedding. Because silk fibers are very long, they tend not to shed as easily as hair fibers.

Plant fibers are specialized plant cells. They are grouped by the part of the plant from which they come. Seeds, fruits, stems, and leaves all produce natural plant fibers. Plant fibers vary greatly in their physical characteristics; some are very thick and stiff, whereas others are very smooth, fine, and flexible. Some are **amorphous**, a loose arrangement of fibers that are soft, elastic, and absorbent. However, all plant fibers share the common polymer cellulose. Cellulose is a polymer that is made up of simple glucose units, and is not protein. Proteins and cellulose have very different chemical and physical properties that allow a forensic scientist to tell animal and plant fibers apart. For example, cellulose can absorb water but is insoluble (will not dissolve) in water. It is very resistant to damage from harsh chemicals and can only be dissolved by very strong acids, such as sulfuric acid. Cotton is the most common plant fiber used in textiles (Figure 4-5).

Plant fibers are often short, two to five centimeters, and become brittle over time. This means that small pieces of fibers are common as trace evidence at a crime scene.

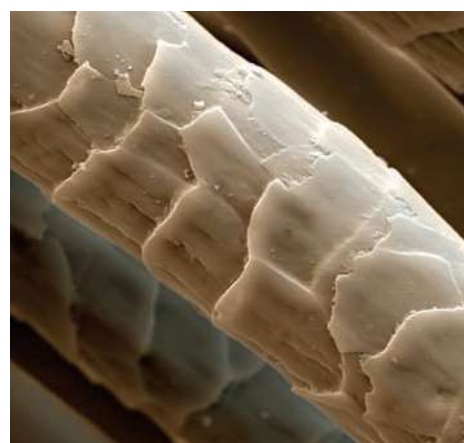
Seed fibers Cotton is found in the seedpod of the cotton plant. Because of the ease with which cotton can be woven and dyed, it has been used extensively for clothing and household textiles.

Fruit fibers Coir is a coarse fiber obtained from the covering surrounding coconuts. The individual cells of the coir fibers are narrow, with thick walls made of cellulose. When woven together, they



Silk cocoons are 2.5 cm long and are made from one fiber that may measure 1 to 2 km long! However, it takes 3,000 of these cocoons to make 1 square meter of fabric.

Figure 4-4. A polarized light micrograph of wool fibers.



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Figure 4-5. A ripe cotton boll showing the cotton fibers.



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Figure 4-6. Coir fibers are often used in things like floor mats because they are so durable.



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Figure 4-7. The rough fibers of jute are made into rope and twine.



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are stronger than flax or cotton. Coir fiber is relatively waterproof, which makes it ideal for such things as doormats and baskets (Figure 4-6).

Stem fibers Hemp, jute, and flax are all produced from the thick region of plant stems (Figure 4-7). They do not grow as single, unconnected fibers like cotton, but in bundles. These bundles may be six feet in length and extend the entire length of a plant. During processing, the bundles are separated from the stem and beaten, rolled, and washed until they separate into single fibers.

Flax is the most common stem fiber and is most commonly found in the textile linen. This material is not as popular as it once was because of its high cost. Linen is a very smooth and often shiny fabric that resists wear and

feels cool in hot weather. Pants, jackets, and shirts are the most common garments made from linen. It is also common as tablecloths and bedding. Linen is unique because it is highly **crystalline**, so it is a dense, strong fiber that resists rot and light damage.

Other stem fibers include jute and hemp. Jute fibers produce a textile that is too coarse for garments and is instead used to make rope, mats, and handbags. Hemp is

similar to flax and has been used for a long time in Asia for clothing. It has recently become a popular alternative to cotton in North America.

Leaf fibers Manila is a fiber extracted from the leaves of abaca, a relative of the banana tree. The fiber bundles are taken from the surface of the leaves. A fiber bundle, composed of many fiber cells bound together, can reach a length of ten feet. Sisal, a desert plant with succulent leaves, also provides fibers, which

Digging Deeper

with Forensic Science e-Collection

Sometimes a murder victim's body is burned to hide the evidence, but rarely are the remains so destroyed that no fibers remain. Are heated and charred fibers useless to forensics? Explore what happens to heated fibers by reading the following two articles from the Gale Forensic Sciences eCollection. You can find the Gale Forensic Science eCollection on school.cengage.com/forensicscience. Then, write a one- to two-page essay defending whether burning a body successfully hides the evidence. Provide reasons for your position.

Jolanta Was. "Identification of thermally changed fibers." *Forensic Science International* 85.1 (Feb. 7, 1997): pp. 51–63.

Jolanta Was-Gubala and Wolf Krauss. "Damage caused to fibers by the action of two types of heat." *Forensic Science International* 159.2-3 (June 2006): p. 119(8).



are used for making ropes, twines, and netting. It is commonly found as a green garden twine, or on farms as the twine on hay bales. These uses take advantage of the fiber's quick deterioration.

Mineral fibers are neither proteins nor cellulose (Figure 4-8). They may not even be long, repeating polymers. Fiberglass is a fiber form of glass. Its fibers are very short, very weak, and brittle. Rolls of fiberglass batting (layers or sheets of fiberglass) are used to insulate buildings. The fibers are very fine and easily stick to the skin, causing an itchy skin rash.

Asbestos is a mineral naturally occurring in different types of rocks with a crystalline structure composed of long, thin fibers. Asbestos is very durable. Its many uses include pipe coverings, brake linings, ceiling tiles, floor tiles, fire-resistant work clothes, shingles, home siding, and insulation for building materials.

Synthetic (Man-made) Fibers

Until the 19th century, only plant or animal fibers were used to make clothing and textiles. Half of the fabrics produced today are **synthetic fibers** (man-made). They are categorized as regenerated fibers and polymers. In simple terms, the fibers are produced by first joining many **monomers** together to form **polymers**. This is done in large vats. This polymer “soup” is then drained out of the bottom of the vats through tiny holes called *spinnerets* to make fibers that can then be spun into yarns. Man-made fibers include rayon, acetate, nylon, acrylics, and polyesters. By changing the size and shape of the spinneret, the qualities (for example., shine, softness, feel) of the textile can be altered. Check your classmates' clothing labels: what man-made fibers are in your classroom?

Regenerated fibers (or modified natural fibers) are derived from cellulose and are mostly plant in origin. The most common of this type is rayon. It is a fiber that can imitate natural fibers and generally is smooth and silky in appearance. Cellulose chemically combined with acetate produces the fiber Celanese® that is used in carpets. When cellulose is combined with three acetate units, it forms polyamide nylon (such as Capron®)—a breathable, lightweight material, used in high-performance clothing.

Synthetic polymer fibers originate with petroleum products and are non-cellulose-based fibers. The fibers are totally man-made polymers that serve no other purpose except to be woven into textiles, ropes, and the like. These fibers can have very different characteristics. They have no definite shape or size, and many, like polyester, may be easily dyed. Distinguishing among the synthetic fibers is easy in a forensics lab, using either a polarizing microscope or infrared spectroscopy.

Synthetic fibers may be very long, or cut and used short. Their shape is determined by the shape of the spinneret and may be round, flat, clover-leaf, or even more complex. However, under magnification, all synthetic fibers have very regular diameters. They do not have any internal structures, but may be solid or hollow, twisted, and pitted on the surface. Depending on what is put into the mix, they may be clear or translucent.

Polyester A very common synthetic fiber, polyester represents a very large group of fibers with a common chemical makeup. It is found in polar fleece, wrinkle-resistant pants, and is also added to many natural fibers to provide additional strength.

Nylon Nylon has properties similar to polyester, except it is easily broken down by light and concentrated acid. Polyester is resistant to both of these

Figure 4-8. Asbestos fibers.

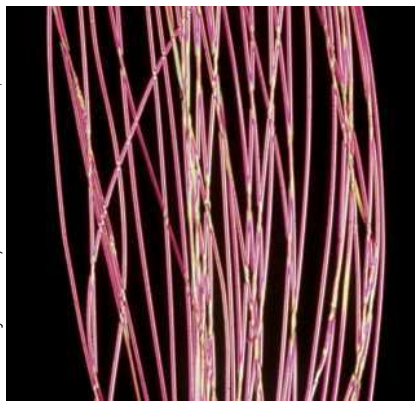


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Asbestos is known to cause cancer. When broken, the fibers shatter into tiny fragments that are light enough to float in air. If we breathe them in, they make tiny cuts in our lungs with every breath we take, and the resulting scar tissue easily becomes cancerous.

Figure 4-9. A polarized light micrograph of nylon fibers.



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agents. Nylon was first introduced as an artificial silk, and synthetic pantyhose still go by the name nylons. Nylon fibers are shown in Figure 4-9.

Acrylic Often found as an artificial wool or imitation fur, acrylic has a light, fluffy feel. However, acrylic clothing tends to ball or pill easily. This is an inexpensive fiber.

Olefins Olefins are used in high-performance clothing, such as thermal socks and carpets, because they are very quick drying and resistant to wear.

Comparison of Natural and Synthetic Fibers

The synthetic fibers are stronger than the strongest natural fibers. Unlike natural fibers, man-made fibers are not damaged by microorganisms. A disadvantage of man-made fibers is that they can deteriorate in bright sunlight and melt at a lower temperature than the natural fibers. The table shown in Figure 4-10 shows the different characteristics of various textile fibers.

Figure 4-10. Descriptions of some common textile fibers as seen under magnification.

Fiber	Characteristics
Cotton	<ul style="list-style-type: none"> • “flattened hose” appearance • up to 2 inches long, tapering to a blunt point • may have a frayed “root” • hollow core not always visible
Flax	<ul style="list-style-type: none"> • “bamboo stick” appearance • straight with angles but not very curved • “nodes” are visible as an X every inch or so • often occur in bundles of several fibers
Silk	<ul style="list-style-type: none"> • do not taper, yet exhibit small variations in diameter • may be paired (raw silk) with another fiber • no internal structures
Wool	<ul style="list-style-type: none"> • surface scales may be visible • hollow or partially hollow core • fibers up to 3 inches long tapering to fine point
Man-made (Synthetic)	<ul style="list-style-type: none"> • vary widely in cross-sectional shape and diameter • generally straight to gentle curves • very uniform in diameter • may have surface treatment that appears as spots, stains, or pits

YARNS

Fibers too short in their raw state to be used to make textiles in their raw state may be spun together to make **yarns**. Short cotton fibers only two centimeters long can be twisted into very strong yarn of any length. Rope is simply a very big yarn. Depending on their use, yarns may be spun thick or thin, loose or tight. Some may be a blend of fibers, such as wool and polyester,

to give desired qualities such as strength or wrinkle resistance. Any given yarn will have a direction of twist. Forensic scientists identify the twist direction as part of their identification (Figure 4-11).

TEXTILES

Weaving originated with basket making. Stone Age man used flax fibers to weave linen cloth. Wool fabrics have been found dating to the Bronze Age. The oldest loom for weaving fabric was found in an Egyptian tomb dating to 4400 B.C. In the early 1700s B.C., the people of China and India developed complicated patterns of weaving fabrics of both silk (China) and cotton (India).

Fibers are woven into textiles or fabrics. Weaving consists of arranging lengthwise threads (the *warp*) side by side and close together (Figure 4-12). Crosswise threads (the *weft*) are then woven back and forth in one of several different patterns. Ancient weavers used a frame to stretch and anchor the warp and either threaded the weft by hand or used a shuttle to alternate the strands of fibers. Machines first performed weaving in the early 1700s.

The pattern in which the weft passes over and under the warp fibers is called the weave pattern. Weave patterns have names like tabby, twill, and satin. Satin is not a type of fiber, it is a type of weave. Look at your shirtsleeve or your pants, and try to identify the yarns that travel in one direction and those that travel at right angles to them.

The simplest weave pattern is the plain, or tabby, weave. It forms a checkerboard, and each weft passes *over* one warp before going *under* the next one. Patterns can be expressed in numbers. A plain weave is a 1/1 weave. The weft yarn goes *over one* warp yarn, then *under one* warp yarn, then *over one* warp, and so on.

Twill weaves are used in rugged clothing such as jeans. Twill is a 3/1 weave. The weft travels *over three* warp yarns, then *under one*, with each successive row shifting over one thread. This creates a diagonal texture on the surface. The two sides of this textile look a little different. Look at the cuff of your jeans and compare the inside to the outside.

A satin weave is a 3/1, 4/1, 5/1, 6/1, or more weave, with the weft traveling *over three or more* warps and *under one*. If the warp and weft yarns are different colors, the textile will be different colors on each side. These and other weave patterns are pictured in Figure 4-13.

Weave pattern is one way that fabrics differ, but it is not the only way. The number of threads that are packed together for any given amount of

Figure 4-11. When fibers are spun into yarn, the twist direction may change as the yarn gets larger.



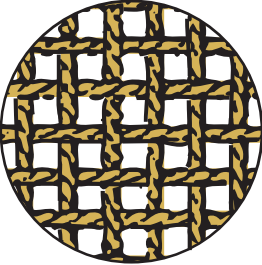
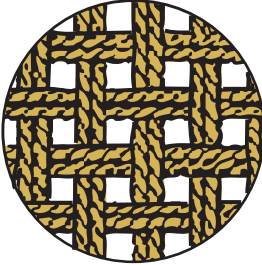
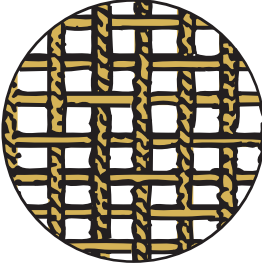
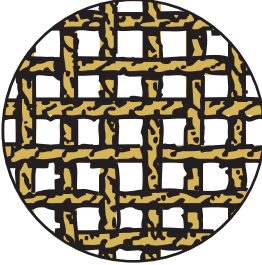
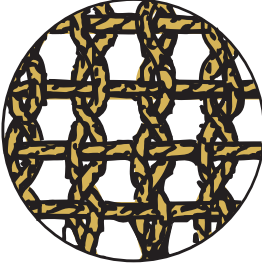
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Figure 4-12. An industrial loom used to weave textiles.



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Figure 4-13. Weave patterns.

Type of Weave	Diagram	Description	Characteristics
Plain		Alternating warp and weft threads	<ul style="list-style-type: none"> • firm and wears well • snag resistant • low tear strength • tends to wrinkle
Basket		Alternating pattern of two weft threads crossing two warp threads	<ul style="list-style-type: none"> • an open or porous weave • does not wrinkle • not very durable • tends to distort as yarns shift • shrinks when washed
Satin		One weft crosses over three or more warp threads.	<ul style="list-style-type: none"> • not durable • tends to snag and break during wear • shiny surface • high light reflectance • little friction with other garments
Twill		Weft is woven over three or more warps and then under one. Next row, the pattern is shifted over one to the left or right by one warp thread	<ul style="list-style-type: none"> • very strong • dense and compact • different faces • diagonal design on surface • soft and pliable
Leno		This uses two warp threads and a double weft thread. The two adjacent warp threads cross over each other. The weft travels left to right and is woven between the two warp threads.	<ul style="list-style-type: none"> • open weave • easily distorted with wear and washing • stretches in one direction only

fabric is another characteristic, which is known as *thread count*. Every package of bed sheets includes information on thread count, as well as the type of fiber used to make them. The price of sheets varies a great deal, and high prices tend to come with all-natural fibers and high thread counts. A high thread count is more costly to manufacture and provides a smoother finish. Thread count is often written as threads per inch. Typical sheets will have a thread count between 180 and 300 threads per inch, but high-quality sheets can have thread counts of 500 threads per inch.

SUMMARY

- Fibers are a form of class evidence used by crime-scene investigators; they are also a form of trace evidence.
- Forensic scientists will try to determine the type of a fiber, its color, how many fibers of each kind were found, where they were found, what textile the fiber came from, and whether there were transfers of multiple types of fibers.
- Fiber evidence may be gathered using special vacuums, sticky tape, or with tweezers.
- Fibers may be analyzed using polarized light microscopy, infrared spectroscopy, burn tests, or tests for solubility in different liquids.
- Fibers may be classified as natural or synthetic.
- Natural fibers include animal hair, plant fibers from seeds, fruit, stems, or leaves, and mineral fibers.
- Synthetic fibers include regenerated or modified natural fibers and synthetic polymer fibers.
- Fibers are spun into yarns that have specific characteristics.
- Yarns are woven, with different patterns, into textiles.

CASE STUDIES

The Murder of George Marsh (1912)

Four bullets were found in millionaire George Marsh's body. Evidence indicated that he had not been robbed. A piece of cloth and a button were found near the corpse. In the rooming house where Marsh lived, an overcoat missing all of the buttons was found in the abandoned room of Willis Dow. The weave of the overcoat matched the weave pattern of the piece of cloth found at the crime scene. Based on this fiber evidence, Dow was convicted of the murder and sentenced to death.

Roger Payne (1968)

Bernard Josephs arrived home to find his wife dead. She had been wearing a purplish-red (cerise) woolen dress. On examination, it was determined that Claire Josephs had been choked into unconsciousness and then had her throat cut with a serrated knife. There was no forcible entry, and Claire appeared to have been in the middle of cooking. This indicated to the police that the murderer was probably someone Claire knew.



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Suspicion fell to an acquaintance of the Josephses named Roger Payne. On examination of his clothing, more than 60 of the unusual cerise-colored fibers were found. These fibers led to the further examination of Payne's clothing, and fibers from a red scarf similar to Payne's were found under Claire's thumbnail. Additional evidence led to the conviction of Payne and the sentence of life imprisonment.

John Joubert (1983)

The body of 13-year-old newspaper boy Dan Eberle was found bound with a rope. His body showed numerous knife wounds. The FBI Behavioral Science Unit compiled a profile of the killer. The profile included the possibility that the killer was a white, slightly built male, about 20 years of age, neat in appearance. The only other real clue was the rope used to bind the victim. It was very unusual in appearance.

More than two months later, a woman working at a daycare center noticed a man watching the children from his car. She wrote down his license number, which led police to John Joubert, a slightly built radar technician at Offutt Air Base. Joubert seemed to fit the profile provided by the FBI. On examination of his possessions, a hunting knife and a length of rope was found. The rope was unique, having been brought back from Korea. It matched rope found at the crime scene. When confronted by the evidence, Joubert confessed. He was found guilty of Eberle's murder and two others.



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Think Critically Based on these case studies, explain why fiber evidence may be crucial to solving a crime.

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CAREERS IN FORENSICS



Irene Good

Irene Good spends her days with fabrics that come from times and places we can only imagine. She is a textile expert who uses her knowledge of fibers and weaving to understand the lives of people who lived long ago. Just how much can be told from a single fiber might be surprising to many archaeologists, although a forensic scientist might understand.

For example, silk threads found in the hair of a 2,700-year-old corpse buried in Germany were once thought to be evidence of trading with China, whose people were manufacturing silk at that time. Good, however, used her fiber analysis skills to test the theory. Using chemical tests, she looked at the protein of the silk threads very closely. So closely, in fact, that she looked at the building blocks of the protein—the amino acids. This told her that the silk found in Germany was not from *Bombyx mori*—the silkworm—and hence was not from China after all. It was from a wild type of silkworm found in the Mediterranean. At once, Good dispelled this key evidence of a trade route between China and Europe hundreds of years ago and revealed new evidence of an ancient European silk industry.

Good has examined ancient textiles of all kinds. On 3,000-year-old mummies from a site in China,



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Irene Good.

she found garments made of cashmere—the oldest known cashmere threads in the world. She was able to identify the hair by its fibers' shape, fineness, and diameter. Not only does the discovery show that the people in China were farming goats to use their hair to make clothes this long ago, but it also reveals that they were highly skilled at spinning.

Good remembers being fascinated by textiles as a child, while growing up on Long Island. She learned to crotchet from her grandmother. Her parents encouraged the fascination by giving her a loom, and Good made her own cloth at home and also spun her own wool. But she pursued a career as an archaeologist with nothing to do with textiles at all. Then one day, by chance, a colleague showed her a fragment of cloth he had found at an excavation site and asked if she could shed any light on the object. She has been using her passion for fibers ever since to solve the mysteries of past cultures.

Good now works at the Peabody Museum at Harvard University. Among other things, part of her work has been to examine a huge collection of ancient garments and fabrics from Peru. Under Good's keen eye, the fabrics are sure to reveal all kinds of secrets about the people of the Andes, the Incas, and how they lived.

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Learn More About It

To learn more about Irene Good and forensic fiber analysis, go to school.cengage.com/forensicscience.

CHAPTER 4 REVIEW

1

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17

Multiple Choice

1. Natural fibers can be harvested from
 - a) plants and animals
 - b) only from plants
 - c) only from animals
 - d) plants, animals, and minerals
2. The shiny nature of silk can be related to
 - a) its hollow core
 - b) its ability to refract light
 - c) its smooth, round fibers
 - d) mucus secretions from the silkworm
3. What characteristics of cotton make it a great source of fiber for clothing?
 - a) It is very easy to grow.
 - b) It is resistant to staining.
 - c) The fibers are easily woven and dyed.
 - d) The fibers are extremely long.
4. Mineral fibers such as asbestos are very durable. These fibers are used in all of the following **except**
 - a) rope
 - b) shingles
 - c) floor tiles
 - d) brake liners
5. All of the following are characteristics of a synthetic fiber **except**
 - a) They are formed by combining monomer compounds into polymer molecules.
 - b) They are man-made.
 - c) They are used in the production of carpet fibers.
 - d) They do not contain any natural fibers.
6. A characteristic of natural fibers is that they
 - a) are stronger than synthetic fibers
 - b) will not break down when exposed to bright light
 - c) melt at a lower temperature than synthetic fibers
 - d) are affected by microscopic organisms
7. Which of the following observations are used to help identify a specific fiber?
 - a) smell of the burned fiber
 - b) on contact with the flame, does the fiber coil or melt?
 - c) color and structure of the residue left after the fiber burns
 - d) all of the above

8. Fibers are an excellent source of trace evidence because
 - a) They are easily transferred from victim to suspect.
 - b) They are often overlooked by a suspect.
 - c) They can be easily collected and stored.
 - d) all of the above

9. A fiber is collected at a crime scene. When viewed under a compound microscope, what two traits would indicate that the fiber was a human hair and not a piece of fiber obtained from an article of clothing? (Choose 2)
 - a) the presence of a cuticle
 - b) a medullary index of 0.33 or less
 - c) a wide diameter
 - d) its ability to dissolve in water

10. Describe the weave patterns of each of the fabrics pictured below. Justify your answer for each.



©Cengage Learning
100% cotton

Weave pattern:



©Cengage Learning
100% wool

Weave pattern:



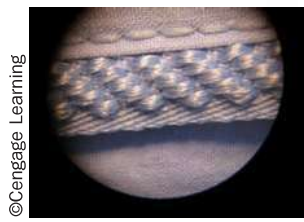
©Cengage Learning
100% nylon rope

Weave pattern:



©Cengage Learning
100% spandex nylon

Weave pattern:



©Cengage Learning

Weave pattern:

100% Cotton blend (hint: more than one pattern)

Questions to Research

11. Explain how the inhalation of asbestos fibers can lead to lung cancer.
12. Explain why roofers removing old asbestos roofs are more at danger of developing lung cancer than a person who installs asbestos flooring.
13. Describe three sources of natural fibers. Provide an example of each type of natural fiber.
14. Silk is a natural fiber produced by the silkworm. How is silk produced by the body of the silkworm?
15. A crime-scene investigator views two small, red fibers. One fiber was obtained from the crime scene off the victim's body, and the other red fiber was removed from the cuff of the suspect's pants. Although the two fibers appear to be from the same fabric, the crime-scene investigator determines that the two fibers are indeed very different. List five other characteristics of the fibers that can be detected under a compound microscope that could be used to distinguish the two red fibers.
16. Fibers collected as trace evidence are often considered to be class evidence and not individual evidence. For example, the presence of a white cotton fiber found on a suspect and found on a victim at a crime scene is not enough evidence to convict the suspect. Justify this statement.

ACTIVITY 4-1

MICROSCOPIC FIBER



Objectives:

By the end of this activity, you will be able to:

1. Identify fibers using microscopic examination.
2. Collect and record data.
3. Apply data collected to solve a forensic problem.
4. Think critically about how well your testing solved the problem and identify possible sources of ambiguity.

Time Required to Complete Activity: 60 minutes

Materials:

Activity 4-1 Lab Sheet

6 microscope slides labeled as follows:

- fibers from Car of Suspect 1
- fibers from Car of Suspect 2
- fibers from Car of Suspect 3
- fibers from Car of Suspect 4
- fibers from Car of the Victim
- fibers found on Victim's Body

colored pencils

microscope

forceps

Safety Precautions:

Always carry a microscope using two hands.

Scenario:

Carpet fibers were found on a murder victim along a roadside. It is speculated that the victim was carried to the location using a car belonging to one of the suspects. Some of the carpet fibers from the floor of the car were transferred to the victim's body. Your task is to match the carpet sample found on the victim's body with one of the carpet samples taken from the cars of four different suspects.

Procedure:

1. View the carpet samples provided by your instructor under the microscope using 100× magnification. Draw sketches of the microscopic view of each carpet fiber sample in the data table.
2. Record the following information:
 - Within a sample are the colors the same or multicolored?
 - Color(s) of the fibers
 - Number of fibers (for example, single, few, numerous)
 - Relative thickness of the fibers (for example, thick, thin, or variable)
 - Shape of fiber (for example, twisted or straight)



Data Table

Source of Fiber	Sketch of Fiber	Single-color or Multi-colored?	Color(s) of Fiber(s)	Relative Number of Fibers (single, few, numerous)	Relative Thickness of Fibers (thin, thick, variable)	Shape of Fiber (twisted or straight)
Car of Suspect 1						
Car of Suspect 2						
Car of Suspect 3						
Car of Suspect 4						
Car of Victim						
Fibers Found on Victim's Body						

Questions:

1. Did any of the suspects' carpet samples match the carpet sample found on the victim? If so, which one?
2. Using specific characteristics from the data table, explain why you thought a particular suspect's carpet sample is a match with the sample found on the victim.
3. Suppose you found a carpet fiber from a suspect's car that did match the fiber found on the victim. What arguments could the defense attorney cite to demonstrate that the matching of the car fibers alone does not necessarily prove that his or her client murdered the victim?



Further Research:

Research what other tests are performed on fiber samples to help match a fiber found at the crime scene with fiber found on a suspect.



ACTIVITY 4-2

BED SHEET THREAD COUNT

Objectives:

By the end of this activity, you will be able to:

1. Determine the thread count of a fabric.
2. Apply knowledge of thread counts, and use critical thinking skills, to solve a forensic problem scenario.

Scenario:

A robbery occurred within a well-to-do neighborhood. The thief grabbed an expensive satin, cream-colored pillowcase to carry out the jewelry that he stole from the jewelry box in the bedroom. Knowing that the items would be listed as stolen goods, the thief immediately took the jewels to a pawnshop to exchange the jewels for money. He carelessly tossed the pillowcase onto the backseat of his car.

Feeling elated at having gotten so much money for the stolen goods, the thief and some of his friends celebrated at the local bar. Having had too much alcohol, the thief was driving erratically. The police stopped the man to give him a ticket for DWI and noticed the cream-colored pillowcase in the back of his car. The dispatcher at the police headquarters had sent out a message for all patrol officers describing the robbery that had occurred that night. No one saw the robber. The only description given was that the robber used a cream-colored satin pillowcase.

Was this the pillow taken from the home where the robbery occurred? Was it satin? Was the color the same? Because many people may purchase cream-colored pillowcases, what other characteristics would the forensic examiner use to match this pillowcase with the other pillowcases found on the bed where the incident occurred?

In this activity, you will examine textile samples and use characteristics such as weave pattern and number of threads to help match a fabric from a crime scene with a fabric found on a suspect.

Background:

The price of sheets may vary tremendously. One company advertises a sale on sheets. Included in the package are a fitted sheet, a flat sheet, and two pillowcases. Total price is only \$40. Another company is selling a sheet that appears to be the same as the sheets on sale, except the two pillowcases alone cost \$40! How can this be possible?

The difference between expensive sheets and the bargain brand results from several factors that affect how soft the sheets feel. Factors affecting this could include:

- a. Type of textile:
 - Muslin
 - Cotton
 - Flannel
 - Satin



- b. Thread count per inch
The greater the number of threads, the more comfortable the sheet, and thus the higher the price.
Thread count is often listed as 180 threads per inch, 200 threads per inch, or 400 threads per inch.
- c. Weave pattern of sheet
Weave patterns of sheets will vary.
The greater the number of threads, the stronger the fabric.

Time Required to Complete Activity: 40 minutes

Materials:

- 3 × 3 square inch sample of bed linens with 180 thread count
- 3 × 3 square inch sample of bed linens with 200 thread count
- 3 × 3 square inch sample of bed linens with 400 thread count
- 3 × 5 card with 1 × 1 square inch cut-out to be used as a thread counter
- magnifying glass or stereomicroscope
- scissors

Safety Precautions:

No safety precautions are needed for this lab.

Procedure:

- Obtain the three bed linen samples.
1. Place the 3 × 5 card with the 1 × 1 square inch cut-out over the middle of each fabric sample.
 2. With the aid of a magnifying glass, count the number of warp threads within the square inch.
 3. Record your data in the data table provided.
 4. With the aid of a magnifying glass or stereomicroscope, count the number of weft threads within a square inch.
 5. Record your data in the data table.
 6. List other distinguishing characteristics of the bed linens in the data table.

Data Table

Sample Number	Warp Thread Count	Weft Thread Count	Characteristics
1.			
2.			
3.			



Questions:

Compare the fabric samples.

1. Are there any distinguishing characteristics that can help identify one fabric over another?
2. If sample one was obtained from the crime scene evidence in the car and sample two came from another pillowcase from the bed of the house that was robbed, would you consider them to be a match? Explain your answer.

Further Research:

The cost of bed linens can vary depending on the quality. Do an investigation comparing less expensive bed linens to those that are much higher priced. Include in your comparison:

- Thread count
- Type of fabric used
- Softness of the fabric
- How well the linens should wear
- Design of the fabric

ACTIVITY 4-3

WEAVE PATTERN ANALYSIS



Objectives:

By the end of this activity, you will be able to:

1. Compare textiles based on their physical characteristics.
2. Identify the weave patterns of textile samples.
3. Apply comparative data to solve a forensic science problem scenario.

Time Required to Complete Activity: 30 minutes

Materials:

Activity 4-3 Lab Sheet
6 different textile samples
label samples 1-5 as being from five different subjects
label sample 6 as crime scene sample

Safety Precautions:

No safety precautions are needed for this lab.

Scenario:

Weave patterns can help identify a fabric associated with a crime scene. In this lab, you are investigating an assault, in which the victim tore off a piece of his attacker's shirt. Five suspects have been taken in for questioning, and a judge has issued a warrant to allow the forensics investigators to look for shirts in the suspects' homes that might match the torn sleeve obtained during the assault. Your task will be to examine each of the suspects' shirts and determine if any of the fabrics match the torn piece from the crime scene.

Procedure:

1. Obtain different textile samples.
2. Using a magnifying glass, examine and identify the weave pattern of each fabric. You may use your textbook.
3. Gently tug on each fabric. Note any difference in stretchability.
4. Record your answers in the data table.



Data Table

Six Different Textile Samples	Weave Pattern	Stretchability (no stretch, some stretch, easily stretches)	Other Characteristics
Suspect 1			
Suspect 2			
Suspect 3			
Suspect 4			
Suspect 5			
Crime Scene Textile			

Questions:

1. Did you successfully match the shirt of one suspect to the fabric from the crime scene?
2. If so, which physical characteristics were most helpful? If not, why not?

ACTIVITY 4-4

TEXTILE IDENTIFICATION



Objectives:

By the end of this activity, you will be able to:

1. Observe and record physical characteristics of fabric samples.
2. Apply knowledge of fabric characteristics to a forensic science problem.
3. Communicate your findings to a lay audience, as though in a court of law.

Time Required to Complete Activity: 45 minutes

Materials:

Activity 4-4 Lab Sheet

(students work in pairs)

four samples of textiles labeled Suspect 1, 2, 3, and Crime Scene, in plastic bags.

masking tape to reseal evidence bags

marking pen to sign evidence bag

compound microscope

3 × 5 card with 1 × 1 square inch cut-out

magnifying glass or stereomicroscope

set of colored pencils

transparency square (or use a 3 × 5 card): Cut out a square 1 × 1 inch. This will be used as a standard to do thread counts.

Safety Precautions:

Always carry a microscope using two hands.

Procedure:

1. Obtain the three chain-of-custody samples of fabric from your instructor.
2. Correctly open the Sample 1 packaging.
3. Examine the sample under 40 × magnification using a compound microscope. (A hand lens or a stereomicroscope may be substituted.) Note the weave pattern for sample one on your data sheet.
4. Using the colored pencils, sketch the weave pattern in the space provided on your data sheet.
5. If a linen tester is available, measure the number of threads per inch in the sample.
6. If a linen tester is not available, use the 3 × 5 card with the 1-inch cut-out, and a stereomicroscope or a magnifying glass, to count the number of threads per inch in the fabric sample.
7. Record the thread count under your sketch.
8. Correctly reseal the evidence in a new evidence envelope and place your signature across the label.
9. Repeat the process for each of the other two suspect fabric samples.

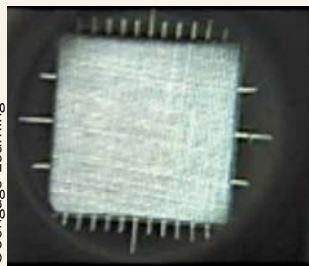
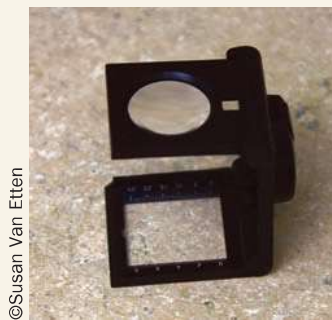
10. Repeat the process for the crime-scene evidence.

11. Return all samples to your instructor.

Linen tester

View through a tester

1 × 1 square inch cut-out



Data Observations and Measurements:

Sample #1

Threads per inch _____

Weave pattern _____

Sample #2

Threads per inch _____

Weave pattern _____

Sample #3

Threads per inch _____

Weave pattern _____

Sample Crime Scene

Threads per inch _____

Weave pattern _____

Questions:

1. After examining the textile samples from Suspects 1, 2, and 3 and the Crime Scene, were you able to determine if any of the fabric found at the crime scene matches the fabric found on the suspect?
2. If so, which suspect had a fiber on them that matched the crime scene?
3. You have been called to court to appear as an expert witness in textiles. You are to report your findings to the jury. Assume the jurors know nothing about textiles. Therefore, you need to define any terms that are not part of normal, everyday conversation. In your discussion, be sure to include the following information.
 - a. Description of fibers
 - b. Thread count
 - c. Weave pattern
 - d. Color of fabric

Remember that your testimony may be used to either link a suspect to a crime scene or to exclude the witness as a suspect.

ACTIVITY 4-5

BURN ANALYSIS OF FIBERS



Objectives:

By the end of this activity, you will be able to:

1. Analyze fibers using a burn test to identify them.
2. Collect and record data.
3. Apply your data to solve a forensic science problem.

Time Required to Complete Activity: 60 minutes

Materials:

Activity 4-5 Lab Sheet

six different labeled fiber samples:

- fibers from car of Suspect 1
- fibers from car of Suspect 2
- fibers from car of Suspect 3
- fibers from car of Suspect 4
- fibers from Victim's Car—Sample 5
- fibers found on the Victim's Body—Sample 6

alcohol or Bunsen burners

forceps

Safety Precautions:

Handle an open flame source with great care. Fibers will ignite suddenly and burn quickly at a very high temperature. Use something that will not conduct heat (forceps are metal and should not be used to hold onto something that is burning) to hold samples in the flame. Wear protective goggles when flame-testing fabrics. Inhaling fumes from burning should be avoided. Work in a well-ventilated area. Make sure a nonflammable surface is placed below the fibers to catch drips or sparks.



Background:

Some very simple tests can be used to determine the type of fibers found at a crime scene. Unfortunately, they are destructive to some of the fibers and consume the evidence. If only a limited number of fibers are recovered from a crime scene, then these tests may not be possible to perform.

Procedure:

Fiber Burn test Tips:

1. Use a sample large enough to determine if the fabric or fiber will continue to burn or die out quickly.
2. Hold the fiber or fabric with the forceps. Try to hold the fabric parallel to the table so that the flames will move across the fabric or fiber. If you hold the fabric so that the fabric droops, the flame will engulf the entire fabric at once. This makes it difficult to determine if the fabric continues to burn after being held in the flame or if the flame dies out.
3. Hold the fabric in the flame for two seconds to ensure that the fabric is ignited.



4. To detect odor of the smoke, it is important to check immediately after the fabric is ignited. You will most likely see a small amount of smoke that disappears quickly. Wave the odor toward your nose with your hand. Describe the odor.
5. Note how the synthetic fibers appear to melt and may give a bubbly appearance as it burns.

Data Table

Source of Fiber	Flame Test (does sample curl as it burns?)	Burn Test (burns or melts? burns slowly or quickly?)	When Removed from Flame (goes out or continues to glow?)	Odor while Burning (tar, burning hair or paper, acrid)	Color and Texture of Residue (beads, ash, crusty, fluffy, round)
Car of Suspect 1					
Car of Suspect 2					
Car of Suspect 3					
Car of Suspect 4					
Car of Victim 5					
Fibers Found on Victim's Body 6					

Questions:



1. Use the information in the data tables along with the Analysis Key which follows to help identify the fibers. Obtain Fiber 1 and proceed through each step of the key beginning with Step 1. Choose the correct alternative path to follow until you have identified the fiber. Repeat for Fibers 2 through 6.

Hint: There should be one fiber of each type. Repeat testing if necessary. Refer to Chapter 4 for reference.

Fiber Burn Analysis Key

When fiber is removed from flame,

1a. It ceases to burn.....	Go to 2
1b. Fiber continues to burn.....	Go to 3
2a. Fibers have the odor of burning hair	Go to 4
2b. Fibers do not smell like hair.....	polyester
3a. Fibers produce a small amount of light ash residue.....	rayon
3b. Fibers produce a gray fluffy ash.....	cotton
4a. A hard black bead results from burning	wool
4b. A brittle, black residue results	silk

2. Which car fibers were matched with those found on the victim?

3. Why were fibers from the victim's car examined?

4. In your analysis, what characteristics make it difficult to distinguish cotton from rayon?