Trace Evidence – How Fibers and Hair are used to aid in Crime Solving.

Locard's Exchange Principal – when a criminal comes in contact with a person or object a cross transfer of evidence occurs.

Fibers – how are they used in court cases?

Dr. Jeffrey MacDonald, Army captain and Green Beret accused of murdering his pregnant wife and two children in 1970, he was made famous in the book and subsequent made for TV movie "Fatal Vision". The investigators were suspicious of the doctor because of the nature of his wounds – suggesting that they were not defensive and perhaps even self inflicted. Blue threads that matched the doctor's pajama top were found under the body of his wife as well as in the bedroom of both murdered children and even under the fingernails of one of his daughters. When MacDonald was confronted with this and other evidence he reportedly stated "You guys are more thorough than I thought". Dr. MacDonald is currently in prison and still maintains his innocence.
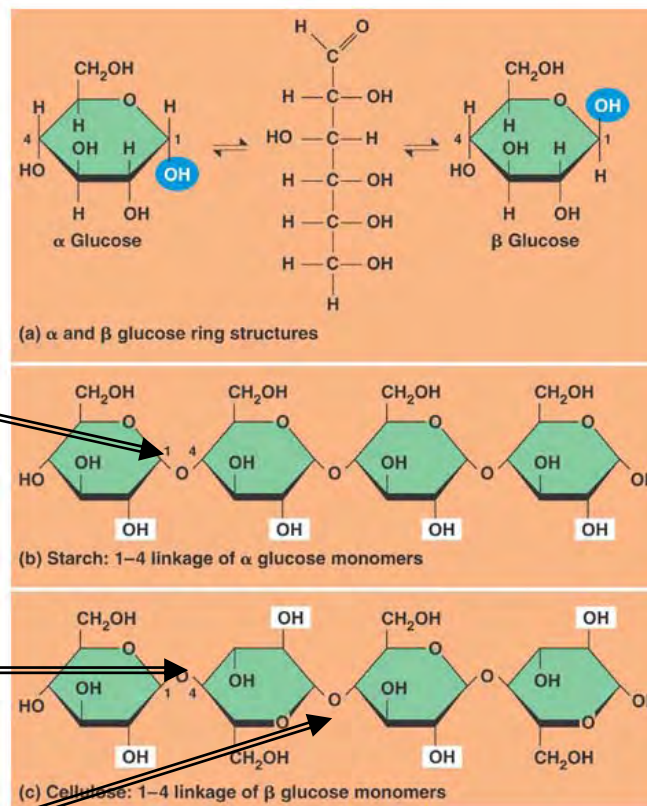
Fiber background:
There are two general types of fibers, natural and manufactured. Natural fibers have been utilized by humans for centuries and are derived from plants and animals. The first manufactured fiber (Rayon – 1911) brought about a great revolution in the variety of fibers available and they have continued to replace natural fibers over the years. See the table below for several examples of each type.

NATURAL FIBERS	MANUFACTURED FIBERS
Wool (sheep)	Rayon
Mohair, Cashmere (goats)	Cellulose acetate
Hair from Llamas, alpacas	Nylon (many varieties)
Fur from rabbit, mink, muskrat and beaver	Polyesters
Cotton (polymer of cellulose)	Spandex

Many of these manufactured fibers are actually synthesized from chemicals that have been joined together in long chains called polymers. The chemicals that the polymers are made from are called monomers. A polymer can be thought of as a long chain made out of repeating monomers.

Seen below is the monomer of cellulose called glucose. The diagram shows two polymers that glucose can form. Starch is the plant storage form of sugar (and what we eat when we enjoy our potatoes! Cellulose is a slightly different organization of the glucose monomers (note the bond angle of the oxygen that connects the glucose rings) and makes a very different polymer.

Same bond angle on each linking oxygen

(a) α and β glucose ring structures

(b) Starch: 1–4 linkage of α glucose monomers

Different bond angle on the linking oxygen

(c) Cellulose: 1–4 linkage of β glucose monomers

Ways to categorize fibers for identification:

There are many ways to identify fibers and we will study how scientists use the following techniques; microscopic analysis, burn testing and solubility, polarizing of light under a microscope and molecule polarity.

Hair - How is it used in court cases?

In the case described above about Jeffrey MacDonald, the defendant and his lawyer had appealed for a new trial as recently as December of 2005 based on hair evidence. From an interview on **Good Morning America**, "We expect that some of the hairs found at the crime scene will not match the MacDonald family member," attorney Andrew Good said. "And will therefore be evidence of intruders." Ultimately, the Supreme Court denied the petition for a new trial, finding no compelling evidence showing the presence of intruders in the family home.

Another case that also shows the importance of hair evidence: A woman was murdered in an alley and next to her was a large flower box with liner. The flower box was analyzed and found to contain tan and navy blue wool fibers and a red acrylic fiber. The woman's clothing was a tan

wool coat, navy wool/polyester blend socks and a red acrylic sweater. The flower box was now definitely linked to the victim. Additionally, light blue nylon fibers and rabbit hair was also found on the flower box as well as the victim's wool coat. Neither of these fibers could be accounted for with her clothing or home. When other evidence led the police to a man who had just sold a full – length rabbit fur coat, a warrant was obtained for his home which contained a light blue nylon rug. The suspect was now tied to the victim and the flower box (part of the murder) due to the presence of the rabbit hair and blue nylon fiber, and was found guilty at trial.
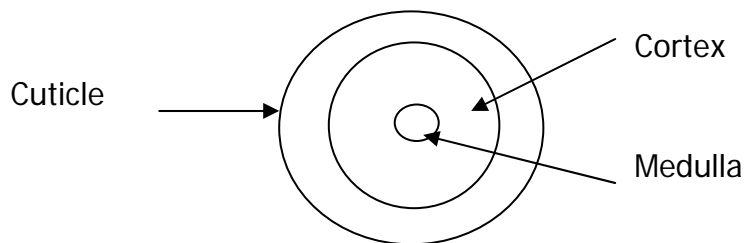
Ways to categorized hair:

Hair is grown out of a hair follicle, an organ in the skin. Hair is categorized two general ways, along the axis (parallel) and in cross section (perpendicular)

Along the hair there is a root, shaft and tip:

Root   Shaft   Tip
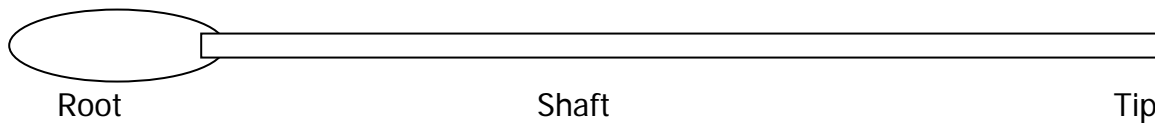
In cross section we will discuss cuticle, cortex and medulla:

Cuticle   Cortex

                          Medulla

Hair has three different growth phases which changes the appearance of the **root**:

- Anagen – initial growth period of hair, lasts up to 6 years. When hair is forcibly removed, some of the follicle comes with it, called a follicular tag. This collection of cells is a much richer source of DNA than hair alone and is useful in generating a DNA fingerprint of the individual it was removed from.

- Catagen – transitional phase where the hair growth is slowing and the being prepared to be shed. Lasts from two to three weeks.
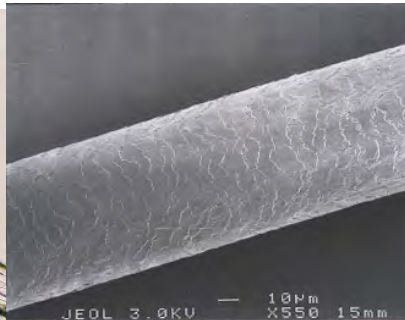

- Telogen – Final phase of growth where the hair naturally falls out without any tissue. This phase will last from two to six months. Then the follicle starts over again with a new hair.

The **cuticle** of the hair is the protective coating that is produced from specialized cells composed mainly of the protein keratin, that have hardened and flattened as they leave the follicle. These scales form a protective layer that prevents the degradation of the hair and aid in the identification. The cuticle cannot tell one individual from another but it is useful in determining the species of the animal the hair is from. Notice the different types of cuticle below:

Spinous cuticle (mink)   Imbricate cuticle (human)   Coronal cuticle (bat)

The **cortex** is made of cells that are parallel along the hair and they contain the pigments that give it color. In order to microscopically analyze the cortex, hair must be within a liquid medium that has the same refractive index so light can penetrate better.

The **medulla** is a "tube" of cells that looks like a canal in the center of the hair. Many animals have a large medulla where the center dark tube is more than half the diameter of the hair. This ratio of medulla diameter to hair diameter is called the **medullary index** and is expressed as a fraction. Humans generally have a medullary index of less that one-third. The medulla can have a large range of patterns that are useful in species identification but not determining one person's hair from another.
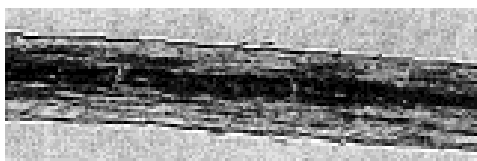
Medullas have three general appearances, as well as many different shapes.

Trace
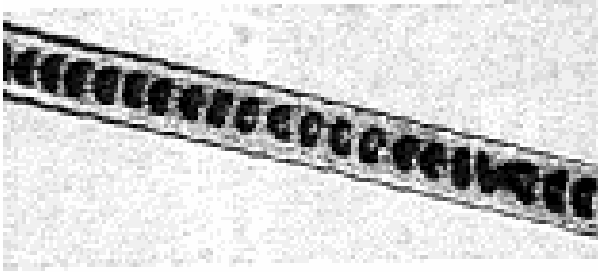
Discontinuous

Continuous

Deer Medulla (notice it is as thick as the hair)
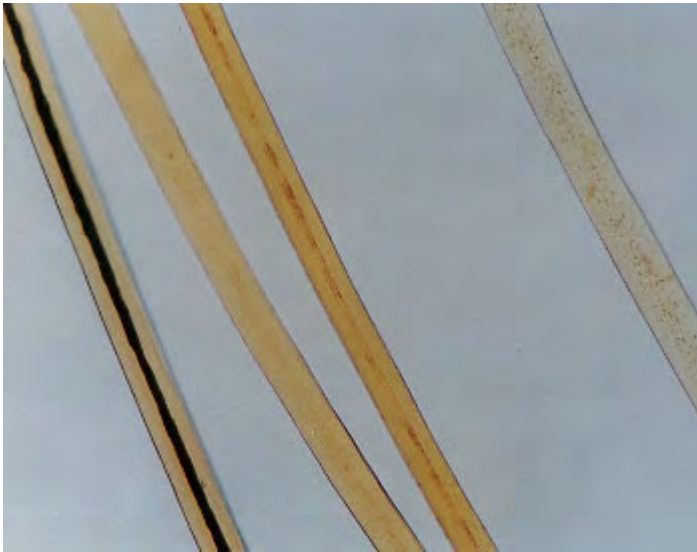

Rabbit Medulla (again the medulla is very large)

Dog medulla

Cat Medulla

Human Hair (many different samples) – can contain a thin or no medulla

Using the information presented on fibers and hair, you should have no difficulties in performing the activities that follow. Enjoy your discovery!

References:
1. Dr. Margaret Frey, Professor of Fiber Science and Apparel Design, Cornell University, Ithaca, NY 14853.
2. AATCC Technical Manual on Fibers (1994) p. 48 -65
3. Forensic Science - An Introduction. Richard Saferstein , Prentice Hall, 2008
4. Hair and Fiber Analysis Lab Activity, Wards Natural Science Establishment, 2006
5. BioDetectives: Investigations in Forensics. "Using Polarized Light to Identify Fibers" Prentice Hall, 2002.

Student Hair Activities

## Activity One – Visualizing the Cuticle by making an impression

1. Collect from your teacher the following items:
   a. forceps (tweezers)
   b. beral (plastic) pipette,
   c. clear plastic metric ruler
   d. small container for water
   e. microscope slides and coverslips
   f. compound microscope
   g. One of each of the known hair samples provided.
   h. Clear nail polish
2. Paint a small amount of nail polish in the center of the slide, let it dry slightly until tacky then carefully place one of your hair samples across the polish. Keep it there several minutes, let the polish mostly dry.
3. Carefully lift the hair straight up out of the polish with the forceps.
4. Examine the impression left by the hair in the polish under a microscope, starting with lowest power and moving to the highest.
5. Record the pattern or draw a sketch of the cuticle in your data chart.
6. Repeat for all your hair samples, including hair from you and at least one other classmate.

Activity Two – Analysis Under a Light Microscope

1. Place a few drops of water onto a microscope slide. Put one of your hair samples on the water and cover it with a coverslip. If your hair is very long, make a figure 8 with it on the slide (be sure to put water drops far enough apart to do this and you may even need two coverslips if they are small).
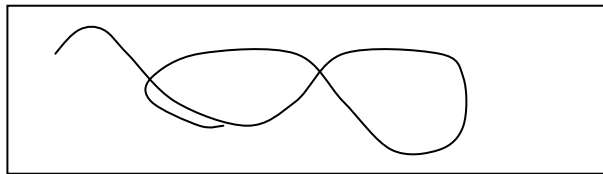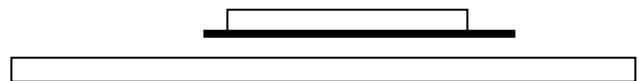
Top view   Side view

2. Examine the hair from root to tip on the compound microscope under the highest magnification. Note the color, how straight or wavy it is, the type of medulla as well as the pattern in the medulla. If you are having trouble figuring out which end of the hair is the root, you can Rub your finger and thumb up and down the length of the hair. This will always cause the root to move away from your hand because the scales of the cuticle point to the tip, and the ridges on you finger causes the hair to move to the tip.

3. Sketch the hair with the medulla in your data chart.

4. Look at how thick the medulla is, and estimate how much of the hair it occupies. Humans have a medulla that is either absent or less than 1/3 the width of the hair, where as some animals have a medulla that is more than ½ the hair width. Record your estimate as the medullary index.
5. Repeat for all your hair samples.

Activity Three – Looking at Human roots and classifying the stage

1. Compare your root (if there is one) with the diagrams provided and decide which of the three phases it might be in; anagen, catagen or telogen
2. Record your observations on the data chart
3. Repeat for all your hair samples

Activity Four – Identification of an Unknown Hair

Your instructor will give you several samples of unlabeled hair. Your job is to compare them to your data table and decide what they are.

Data Table for Hair Analysis:

Hair Sample	Sketch of cuticle scales	Sketch of hair including medulla	Medullary index	Root phase	Additional observations
Dog					
Cat					
Rabbit					
Horse					
Person #1					
Person #2					
Unknown #1					
Unknown #2					
Unknown #3					