Hair Evidence

Scientific Reliability

Scientific Working Group for Material Analysis (SWGMAT) Hair Subgroup

Edited 2013

What is Trace Evidence?

- Evidential material that is usually small, can provide information about an event of interest in an investigation, and often utilizes microscopical or micro-analytical techniques for analysis.

- Trace evidence includes:
  - Hairs
  - Fibers
  - Paint
  - Glass
  - Soil
  - Tapes
  - Feathers
  - Building materials

What is a Hair?

- A fibrous outgrowth from the skin of mammals

How Hairs Become Evidence

During the course of the normal hair growth cycle, hairs are shed from individuals, and these hairs may be deposited during criminal activity. Additionally, hairs may transfer after being pulled, cut, or broken during an activity.

- Hairs may transfer from one person/surface to another
- These deposited hairs occur through direct or indirect (via an intermediate object) transfers

The Locard Exchange Principle

Edmond Locard was a forensic scientist who formally articulated the foundation for the transfer event (Locard 1920). This transfer is often referred to as Locard's Exchange Principle.

> *"The truth is that no one can act with the intensity required for criminal action without leaving multiple signs of his passage. The types of evidence that I want to show here are of two different kinds: sometimes the criminal has left signs of his presence at the scene, sometimes through an inverse action he has taken with him on his body or his clothes signs of his presence or of his actions."*

Courtesy of Patrick Buzzini. Translated from French version: Locard E. L'enquête criminelle et les méthodes scientifiques. Flammarion, Paris (1920) : 139

Transfer and Persistence

Once hairs are transferred to a surface, they will persist on that surface for some time. The duration of persistence will be dependent on the circumstances following deposition.

- Numerous authors have investigated the mechanisms involved in transfer and persistence of hairs/fibers in forensic cases, including Pounds and Smalldon 1975a, 1975b, 1975c; Kidd and Robertson 1982; and Robertson, et al. 1982.

Transfer / Persistence Findings

- Gaudette and Tessarolo (1987) conducted several experiments on hair transfer and stated that many of the variables affecting fiber transfer and persistence were also important in hair transfer and persistence.

- Robertson and Somerset (1987) conducted a similar study on persistence and found comparable results; that is, most transferred hairs are lost with normal activity after about three hours.
- The number of hairs/fibers transferred depended on the nature of the transferred material, the recipient surface, the pressure involved in the contact and the duration of the contact.
- With regard to persistence, the size of the transferred fiber, and the nature and post-deposition activity of the recipient garment/surface, had dramatic effects.

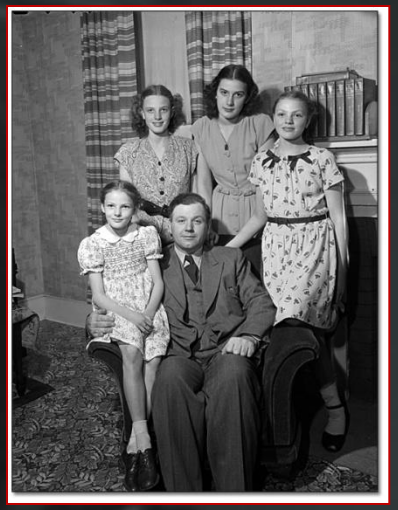
Mechanisms of hair transfer

- Direct (primary) transfer is when trace evidence transfers "directly" from its source to another person/object.

- Indirect (secondary, tertiary, et al.) transfer is when trace evidence is transferred from its source to another person/object via an intermediate person/object.

Additional Transfer Studies of Interest

- Quill (1985) recovered 81 foreign hairs from his clothing over a 31 day period and found that of the hairs suitable for comparison, all had been transferred from his family members. He concluded that for a foreign hair to be present on clothing, close personal interaction is necessary.
- Simons (1986) conducted studies with regard to laundering and found that although most hairs are removed from clothes during the laundering process, some do remain and hair transfers can occur as a result of laundering.
- Peabody et al. (1985) investigated the shedding of hair into various headgear. They found that the number of hairs shed varies with the type of headgear worn and with the individual. They also noted the importance of collecting head hair combings because the hairs shed in their study were more similar to the naturally shed hairs encountered in combings than in plucked hair samples.



Recovery of Hairs from Evidence

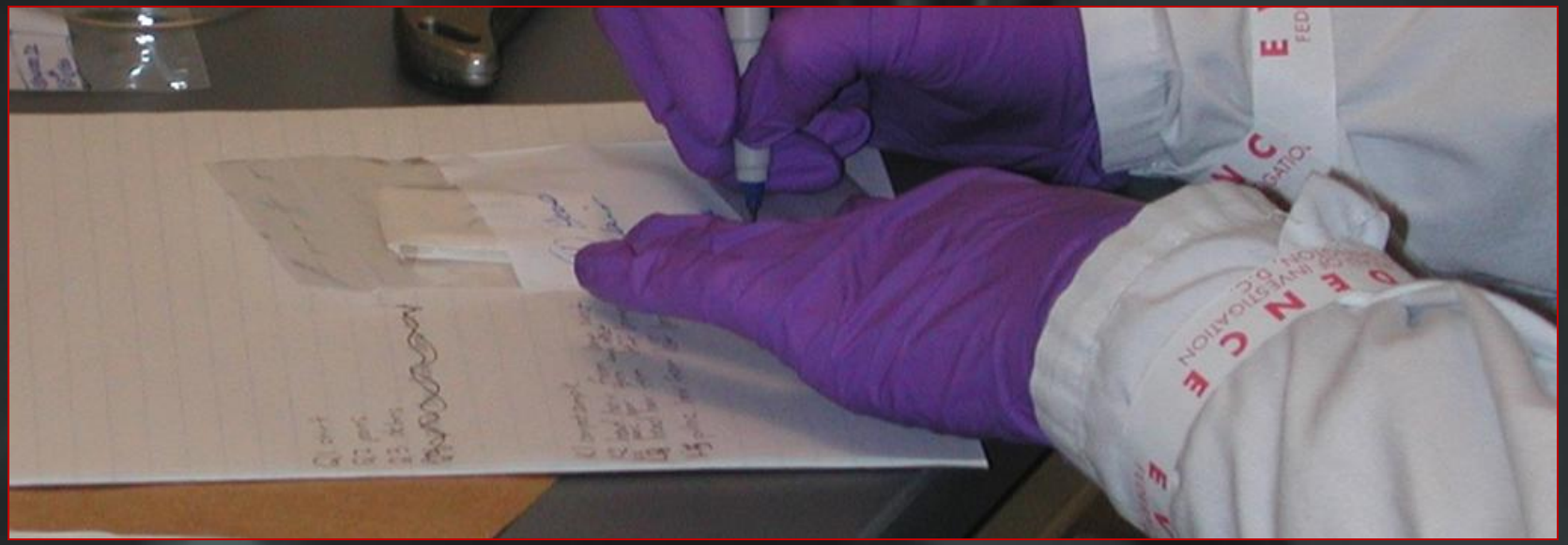
Hairs can be recovered from items of evidence in a variety of ways. Regardless of the technique used, care is taken to maintain the integrity of the evidence by wearing protective clothing such as gloves and lab coats and by examining items from different individuals or scenes separately.

Collection techniques

- Picking
- Taping
- Scraping
- Vacuuming

Hairs are examined with a low magnification microscope and those of interest are mounted on glass slides

Detailed notes are taken during the examination process, and all items are marked with unique lab and item numbers for identification purposes.



Hairs can then be examined with a high-magnification microscope generally ranging from 25X-400X to observe the microscopic characteristics

What may be determined from the microscopic characteristics of hairs?

- If the hair is human or non-human
- If human
  - Racial/somatic characteristics
  - Pulled or naturally shed
  - Damaged
  - Artificially treated
  - Suitability for microscopical comparison
  - Suitability for nDNA or mtDNA

Human Hair

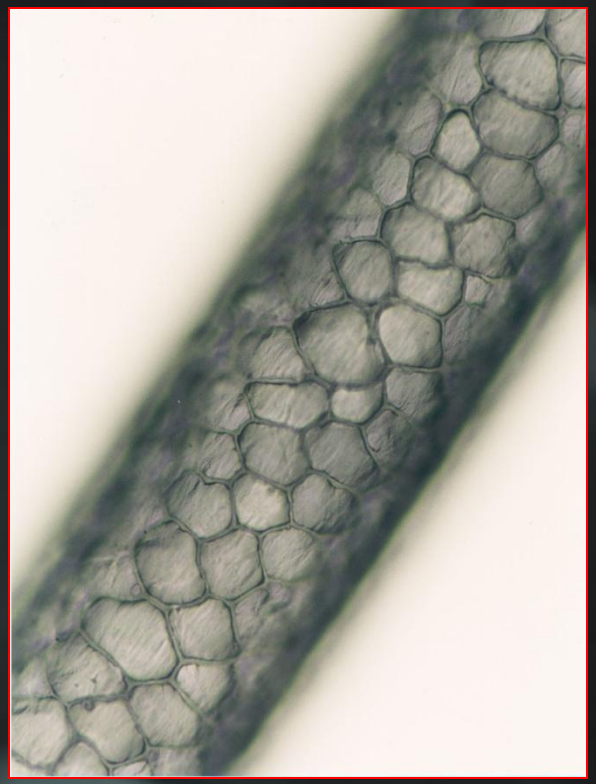
- Humans lose approximately 50-100 head hairs per day
- Most of these hairs are lost during daily grooming activities
- At any given time, approximately 80-90% anagen, 10-20% telogen, 2% catagen
- Average growth cycle of head hair = 2 - 6 years
- Head hair grows approximately ½ inch per month in humans
- 90,000 - 150,000 hairs on head
- Approximately 2 million follicles on body

Microscopic Characteristics of Hairs

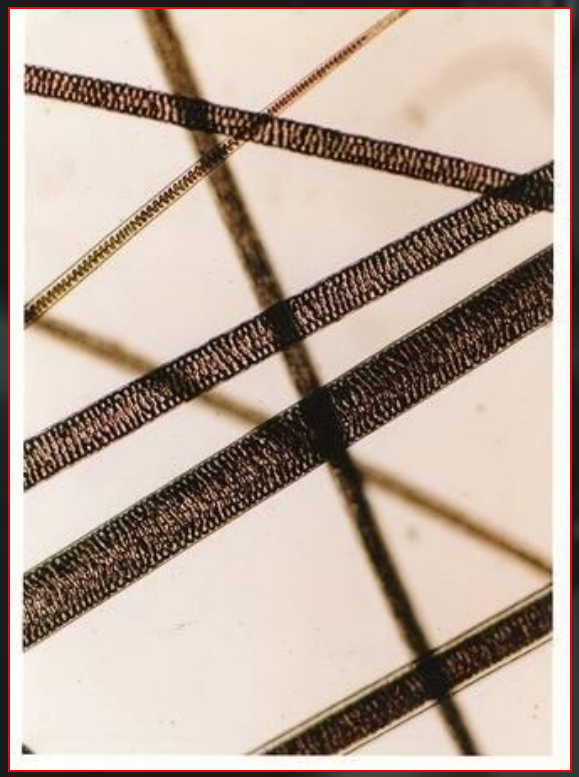
The morphological characteristics in hairs are examined and compared

Hair Identification – Species/Genus

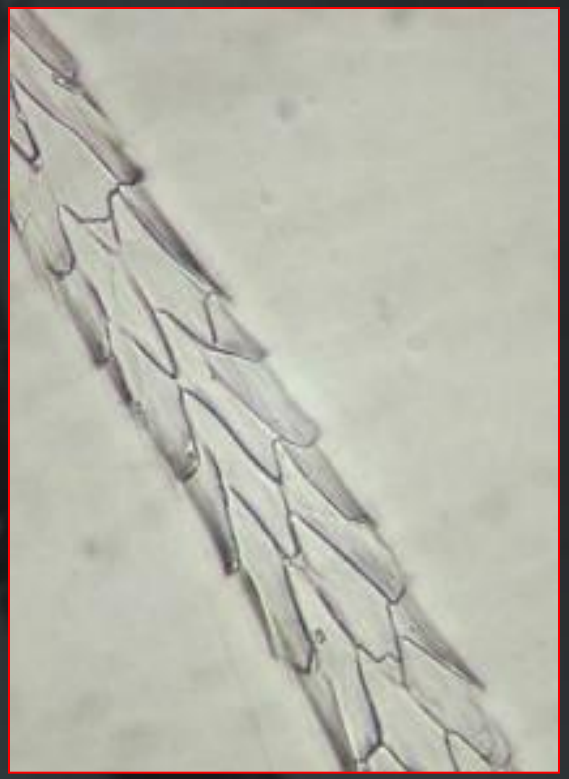
The microscopic characteristics allow for hairs to be categorized as human or non-human. If animal (non-human) - the genus or species can usually be identified.



Deer



Squirrel

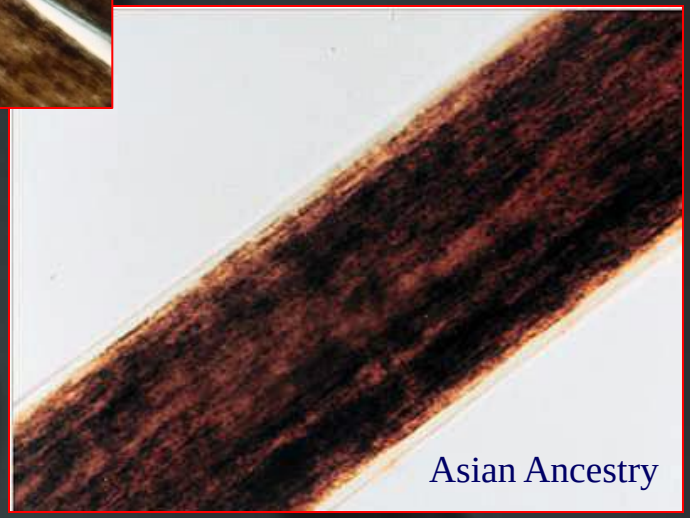


Mink

Human Hairs – Racial Characterization

- European Ancestry (Caucasoid)
- African Ancestry (Negroid)
- Asian / Native American Ancestry (Mongoloid)
- Mixed Racial – A combination of racial characteristics

This does not imply that a person's race can be determined by their hair characteristics.



Human Hairs – Determination of Body-Area or Somatic Origin

Macroscopic and microscopic characteristics may allow for a determination of the body area from which the hair originated. The following somatic origins may be determinable:

- Head
- Pubic
- Facial (beard and mustache)
- Eye (eye lash and brow)
- Limb (arm/leg)
- Torso (e.g., chest, axillary, back, abdominal)

Hairs may be encountered which cannot be categorized into one of these groups. These may be “transitional hairs” (those growing between two body regions).

The Comparison Microscope is used for side-by-side comparisons of questioned and known hairs.

View through the Comparison Microscope

Known hair from Victim

Questioned hair from scene

Hair comparison protocol

- Requires thorough and careful examination of gross and microscopic hair characteristics of properly prepared hairs using a high-quality comparison microscope with different magnifications

Comparison protocol

- All characteristics are considered
- Full-length hairs are preferable
- Comparisons are commonly only conducted with head and pubic hairs since they produce the most meaningful conclusions
- The known hair sample needs to be representative of the variation in the source
- Corresponding parts of the questioned and known hairs must be compared

Comparison microscope

- High quality
  - With good optics and color balance
  - Range of magnification
    - Lower magnification to examine entire hair (generally 40-60X)
    - Higher magnification (generally 100X-400X) for fine detail, scales, pigment and optical sectioning

Microscopic Characteristics - Roots

- In humans, root morphology provides information about growth stage, decomposition, artificial treatment, and may provide comparative aspects.
- Many authors have offered classification schemes for the description of hair roots (Bisbing 1982, Harding and Rogers 1984, Lee and DeForest 1984, McCrone 1982, Shaffer 1982, Strauss 1983)
- In animals, the root morphology may assist in the identification of the type of animal

Deer

Dog

Microscopic Characteristics - Growth Phase

- Anagen – actively growing
- Catagen – transitional phase
- Telogen – inactive follicle, naturally shed

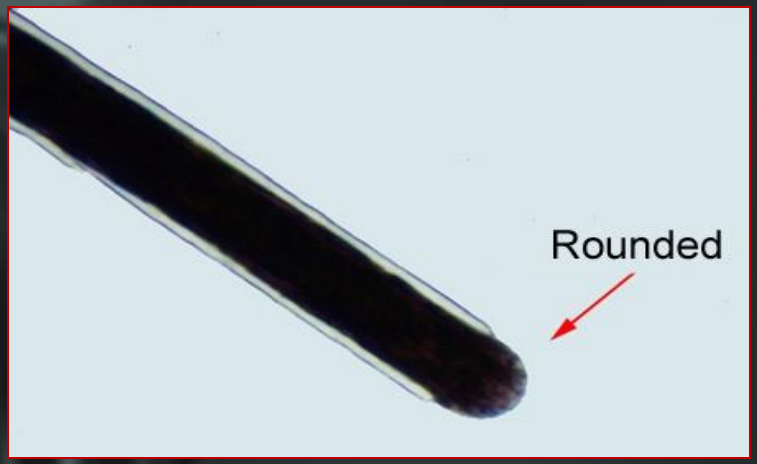
Anagen

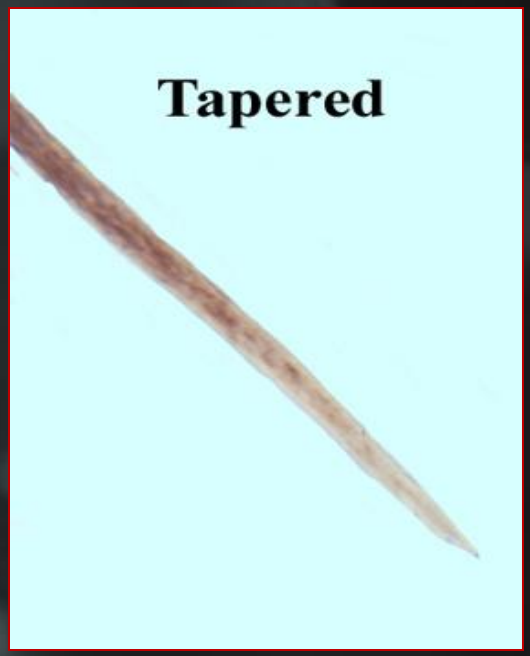
Telogen

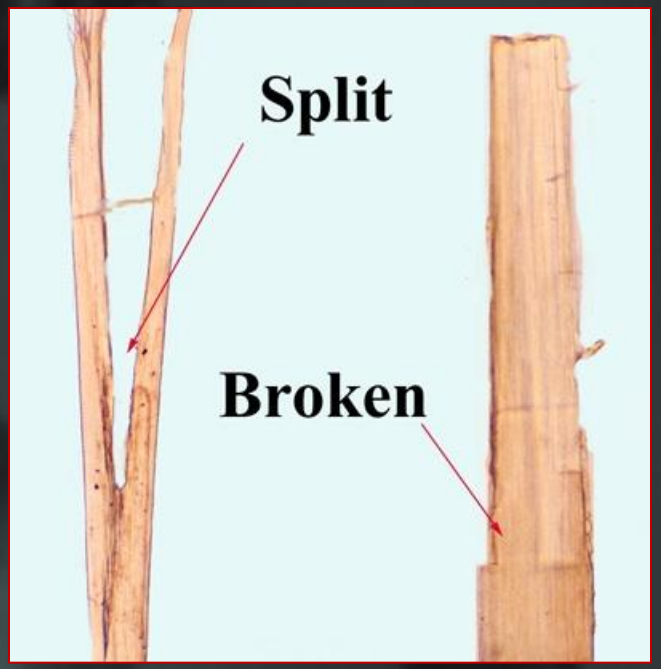
Microscopic Characteristics - Roots

Note variation in appearance that can be seen from one individual to the next

Microscopic Characteristics - Tips

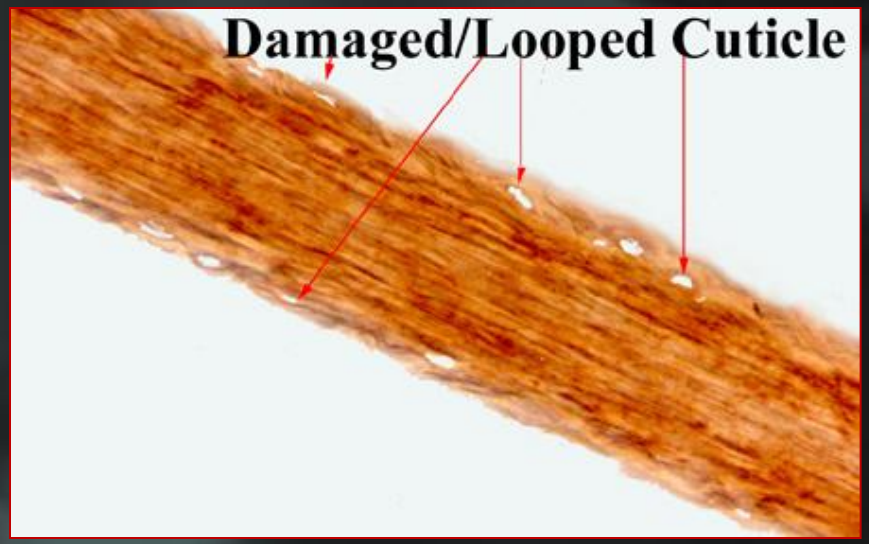






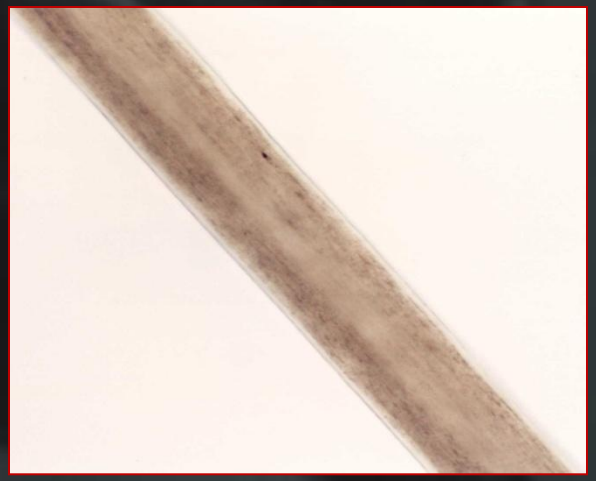
Microscopic Characteristics - Cuticle

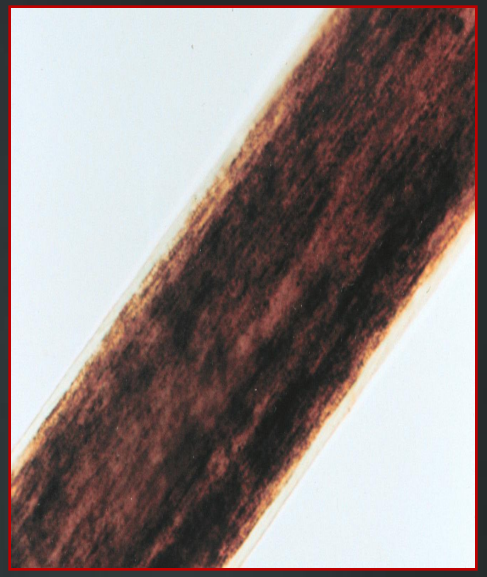
- Scale protrusion
- Thickness
- Color
- Cuticle margin
- Miscellaneous:
  - evidence of cosmetic treatment
  - Cracking, looping

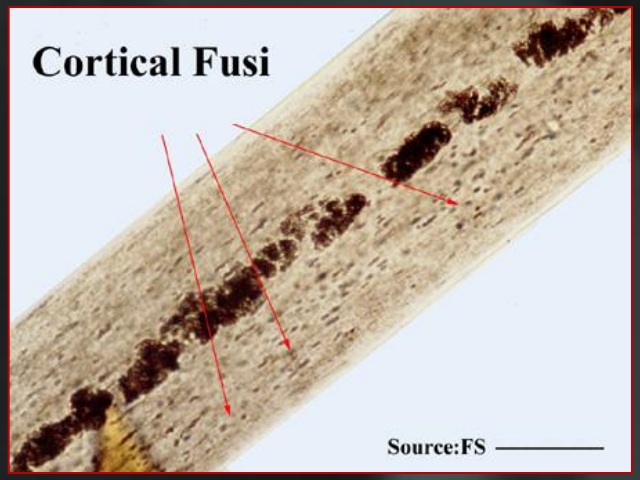


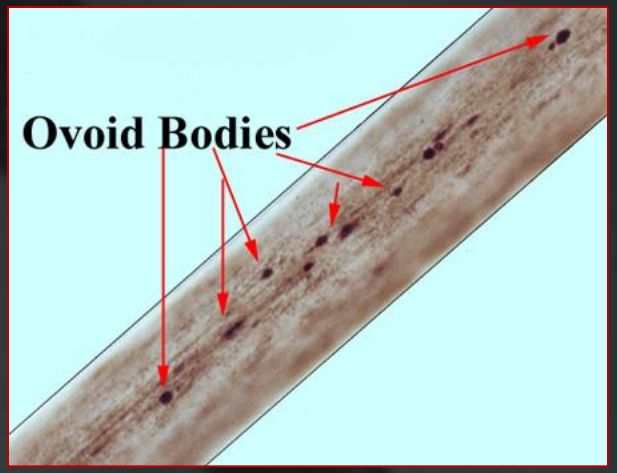
Microscopic Characteristics - Cortex

- Pigment size, distribution, and density
- Texture
- Ovoid bodies
- Cortical fusi



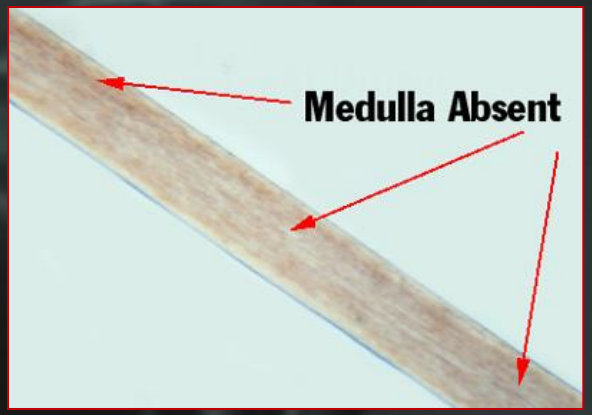


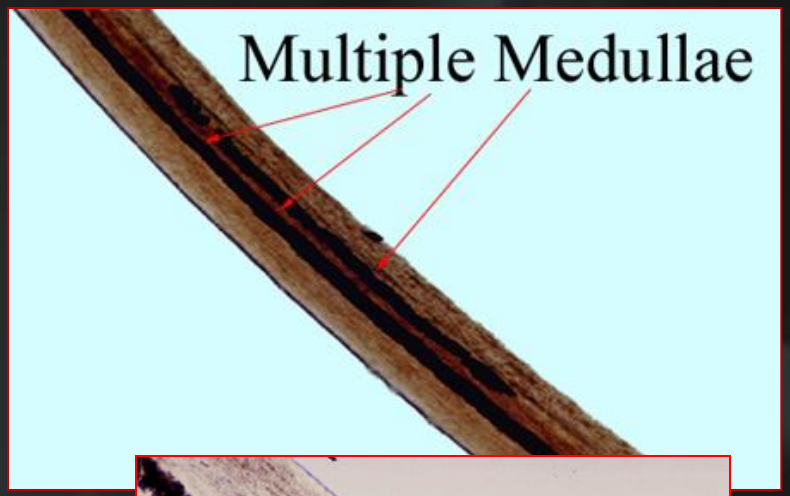


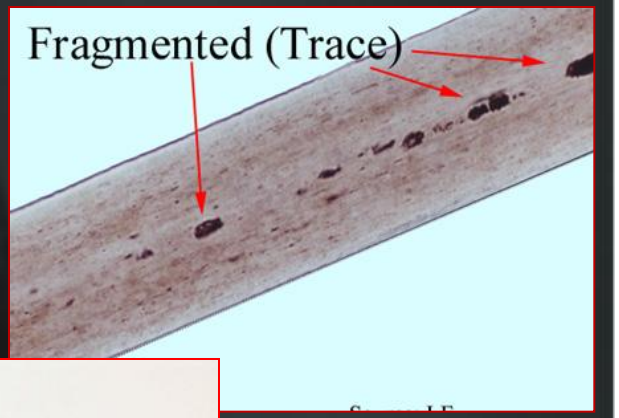


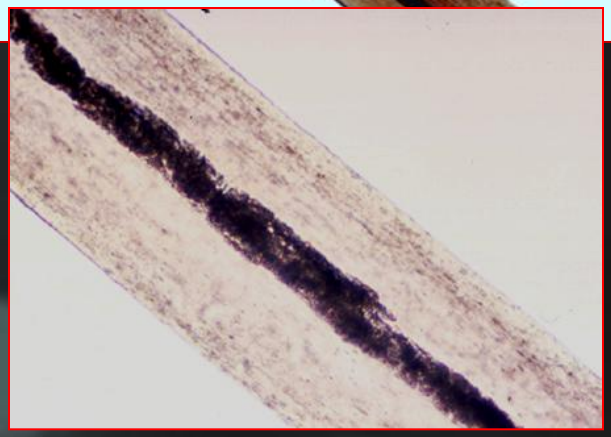
Microscopic Characteristics - Medulla

- Presence or absence
- Appearance
- Size





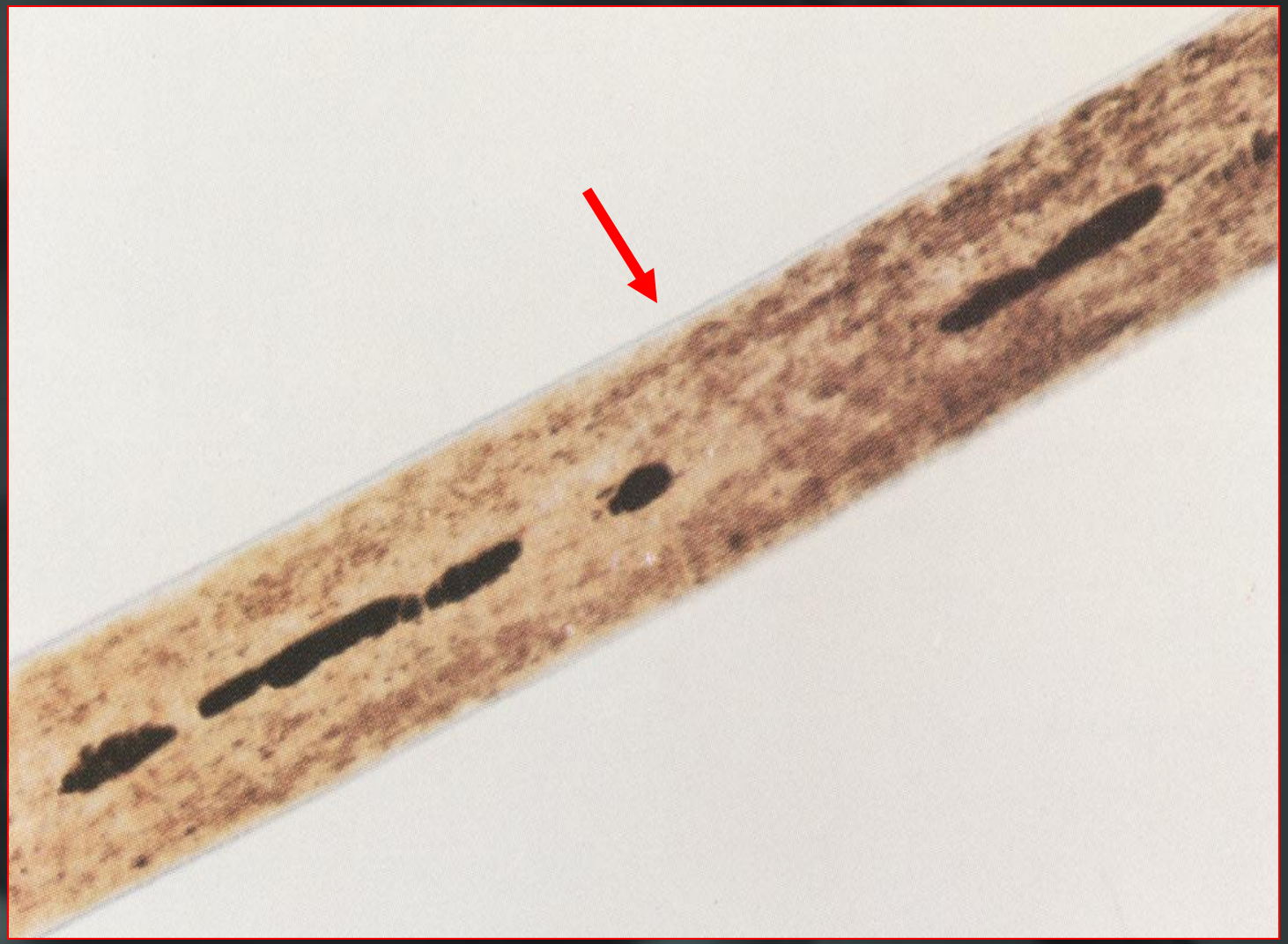




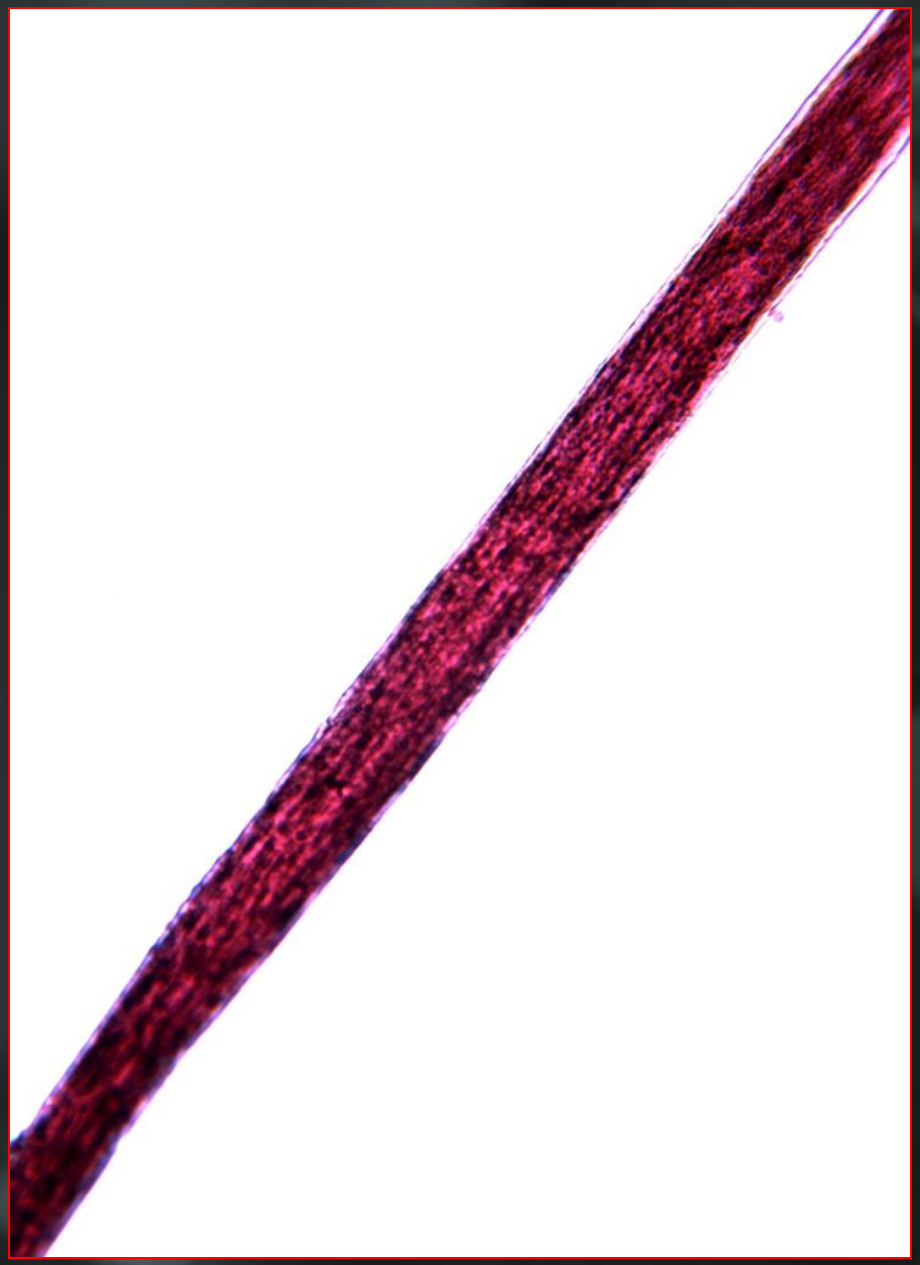
Microscopic Characteristics
Artificial Treatment - Dye

- Distinct color change, clear line of demarcation
- Pigment granules may be bleached out
- Often see color in the cuticle
- Unnatural and/or diffuse color

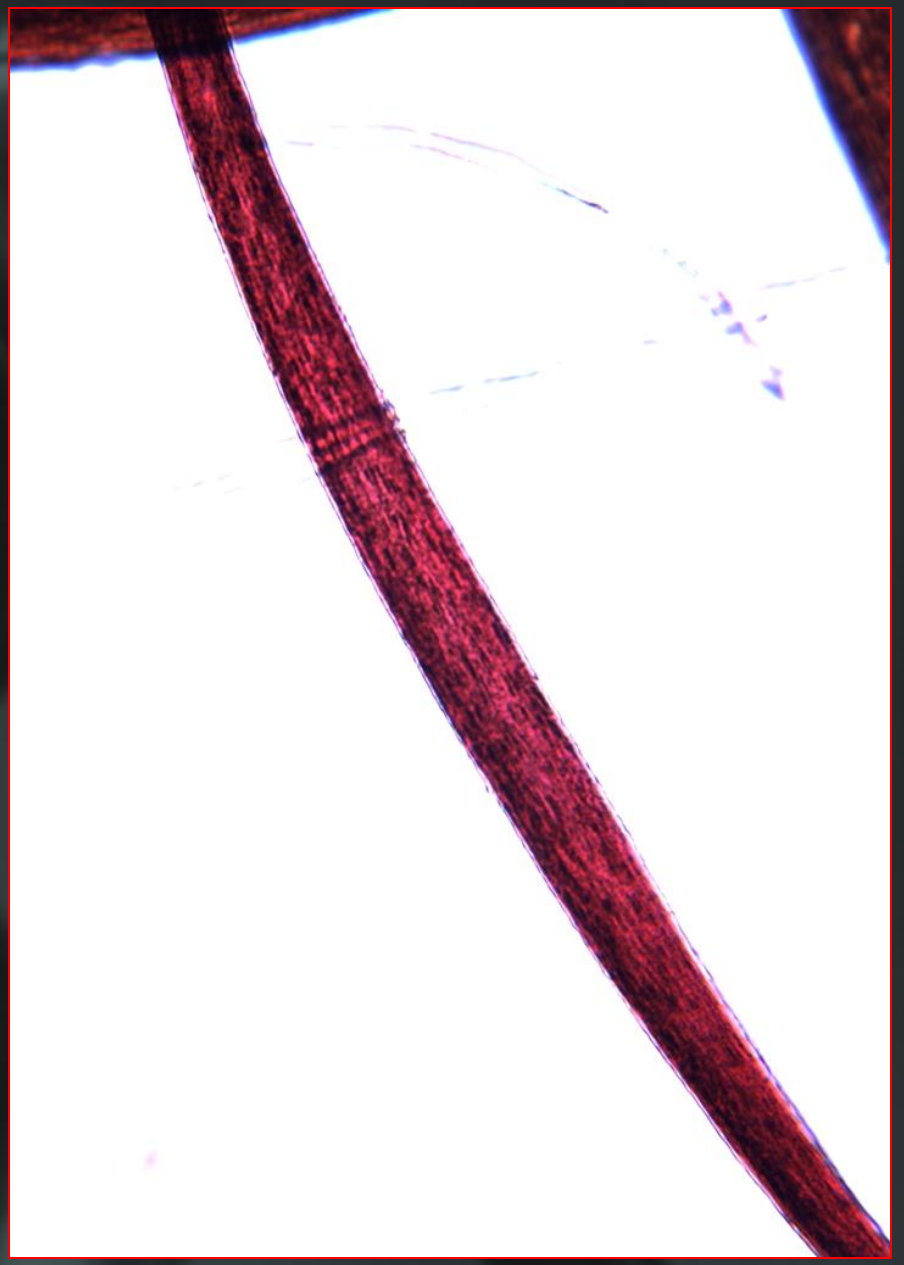
Microscopic Characteristics
Artificial Treatment - Bleached



Known hair sample



Questioned hair from vehicle



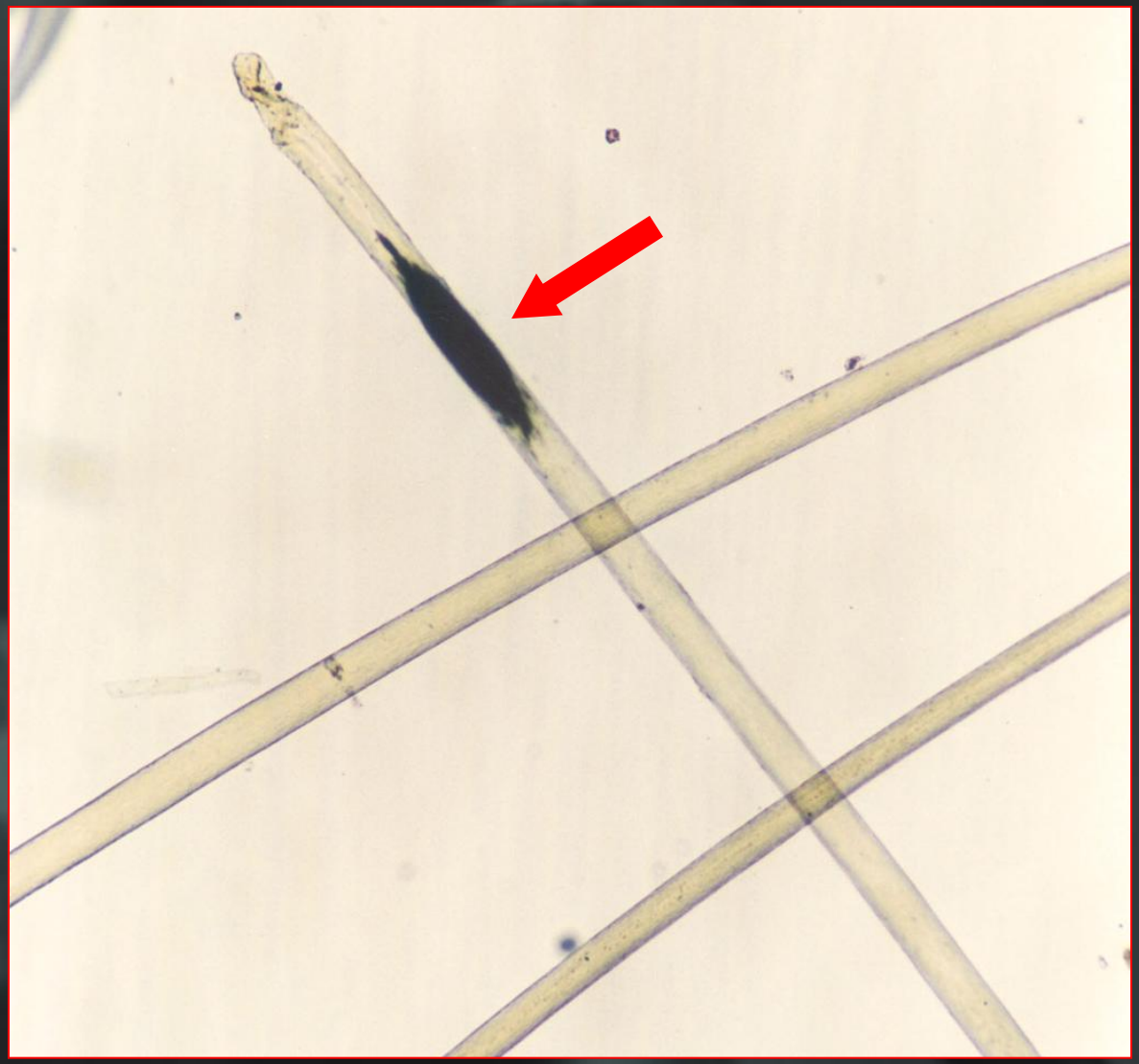
Microscopic Characteristics - Damage

- Crushing
- Burning

Crushed hair

Burned head hair

Microscopic Characteristics - Decomposition

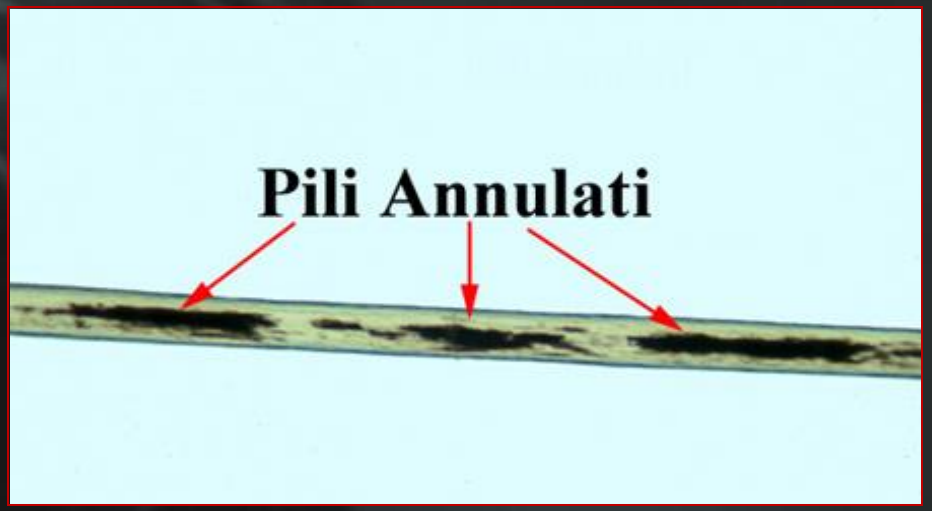


Hair from a decomposing body with postmortem banding

Microscopic Characteristics - Artifacts

Blood on hair

Microscopic Characteristics - Disease



Hair Comparison Conclusions

- The following general conclusions can be reached when performing a microscopical hair comparison:

  - The questioned and known hairs have similar microscopic characteristics and therefore the source of the known hair sample can be included as a possible source of the questioned hair.

  - The questioned and known hair samples have dissimilar microscopic characteristics and therefore, based on the provided known sample, the questioned hair is not consistent with originating from the source of the known hair sample.

  - The questioned and known hair samples exhibit both similarities and differences in their microscopic characteristics; therefore, based on the provided known sample, no determination can be made as to whether or not the source of the known hair sample can be included as a possible source of the questioned hair.

Hair Conclusions Criteria: Association

In order to conclude that two hair samples could share a common origin, it must be determined that there are no significant macroscopic or microscopic differences. It is important to determine what differences are significant because no two hairs are exactly the same in every detail (identical). It must be determined that the characteristics exhibited by the questioned sample fit in the range of characteristics present in the other sample (typically the known sample).

Hair Conclusions Criteria: Exclusion / Non-association

If significant differences exist in the macroscopic and/or microscopic characteristics exhibited by the questioned and known hairs, the questioned hairs cannot be associated with the source of the known hair sample. This conclusion is dependent upon the adequacy of the known sample.

Hair Comparison Significance

- Microscopic hair comparisons are not a means of personal identification.
- The variability of microscopic characteristics in hair between individuals allows for meaningful associations.
- One would not expect to encounter two individuals selected at random in the population to have hairs with the same combination of microscopic characteristics.

DNA Examination of Hair

The combination of microscopical hair comparisons and DNA analysis provides more information and discriminating power than either technique can alone. Microscopical examinations should always precede DNA examinations.

DNA of Hairs

Hair Root with Tissue

Suitable for Nuclear or Mitochondrial DNA testing

Naturally Shed Root

Generally tested for Mitochondrial DNA only

Scientific Basis for Morphological Identifications

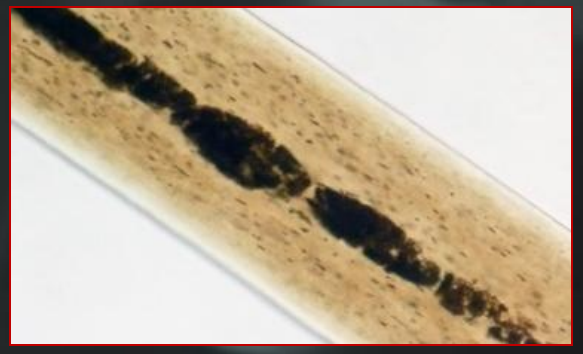
- Comparative biology has a long history of microscopical and morphological identification and comparison dating back to the 18th century.

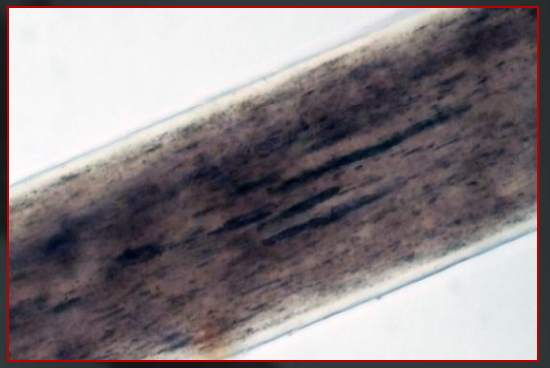
- All organisms differ widely in many characteristics, including morphological appearance, physiology, and genetic makeup which allows them to be classified by a variety of schemes.

Comparative Biology

- Some groups of organisms are clearly more similar to one group than others.





- Hairs can be the subject of scientific study in the same way as all other biological specimens

Technique Testability

- The proposition that hairs from different sources can often be reliably distinguished has been tested by the scientific method in numerous research and casework studies. Thus, one would not expect two individuals, selected at random in the population, to have hairs that possess the same microscopic characteristics.

  - Bisbing, R. E. and Wolner. M. F. Microscopical discrimination of twins' head hair, *Journal of Forensic Sciences* (1984) 29:780–786.
  - Wickenheiser, R. A. and Hepworth, D. G. Further evaluation of probabilities in human scalp hair comparisons, *Journal of Forensic Sciences* (1990) 35:1323–1329.
  - Strauss, M. A. T. Forensic characterization of human hair, *The Microscope* (1983) 31:15–29.
  - Gaudette, B. D. Some further thoughts on probabilities and human hair comparisons, *Journal of Forensic Sciences* (1978) 23:758–763.

Technique Testability

- Comparison/Identification tests
  - During training, a hair examiner completes a series of practical tests in order to become proficient
- Competency tests
  - Before casework is assigned to the hair examiner, a competency test that simulates casework is successfully completed
- Proficiency tests
  - Hair examiners must successfully complete hair proficiency tests in order to continue to conduct casework

Peer Review

- Scientific papers on hair comparisons appear in peer-reviewed journals; examples include:
  - *Journal of American Society of Trace Evidence Examiners*
  - *Journal of Forensic Sciences*
  - *Journal of Forensic Science Society/Science and Justice*
  - *Forensic Science Communication/Crime Laboratory Digest*
  - *Forensic Science International*
  - *Canadian Society of Forensic Science*
  - *The Microscope*

Standards Controlling Technique

- Scientific working groups around the world write standards and guidelines for the examination and comparison of hairs
  - Scientific Working Group for Materials Analysis (SWGMAT)
    - Forensic Human Hair Examination Guidelines
    - Forensic Human Hair Examination Training Program
  - Textile and Hair Working Group of the European Network of Forensic Science Institutes (ENFSI)
- Accredited forensic laboratories conducting hair examinations must develop and follow standard operating procedures

Error Rate

The error rate for a particular hair examination cannot be determined because it deals with a unique event (unique case, unique hair samples, and unique examiner) that cannot be statistically duplicated.

While an error rate cannot be calculated for a specific case, the reliability of the findings is supported by the implementation of quality control mechanisms (e.g. training, proficiency testing, protocols, verifications, peer review).

Error Rate

Quality control mechanisms reducing potential errors:

- The scientist meets the educational requirements for the position
- The scientist received job-specific training for the analysis and comparisons of hairs
- The scientist successfully completed competency testing before starting hair examinations
- The scientist successfully participates in ongoing proficiency testing for hairs
- Probative associations are verified by another examiner
- Cases are subjected to both a technical and administrative review

General Acceptance

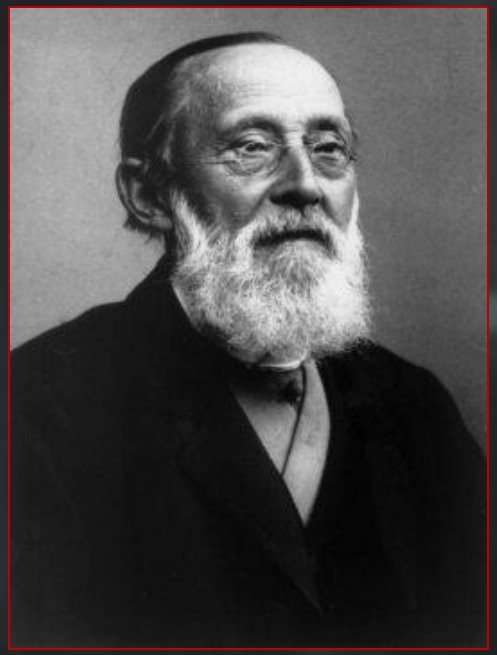
- Microscopical examination and comparison of hairs has been conducted for over a century.
- Federal, state and local/city laboratories routinely conduct hair examinations.
- Comparative biology has a long history of microscopical identification and comparison dating back to the 18th century.
- Microscopical techniques are utilized in a wide variety of scientific disciplines.
- *SWGMAT Guidelines for Forensic Human Hair Examination*

General Acceptance

- The scientific analysis of human hair is not conducted solely by forensic scientists. Hairs are analyzed by the cosmetics industry for development of hair care products and by the medical field to evaluate nutritional status, toxic-element levels, and to diagnose certain dermatological diseases. However, the microscopical comparison of human hairs is largely the domain of the forensic scientist.

General Acceptance

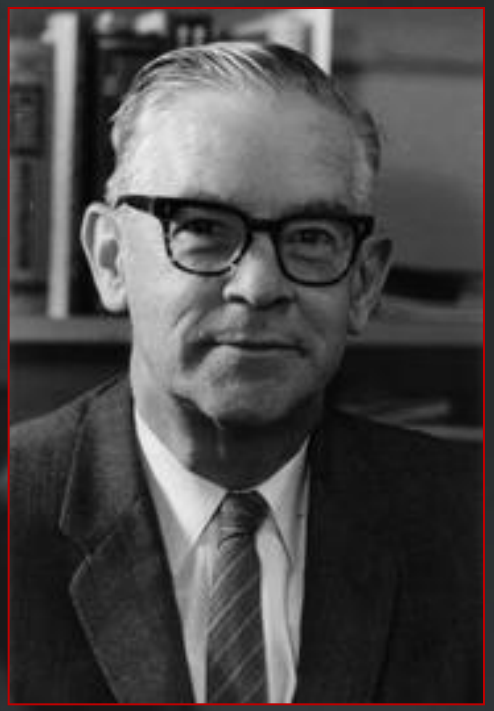
- The first reported use of forensic human hair comparison was by Rudolf Virchow in 1861 (as cited in Bisbing 1982). He reported the following:



"The greatest majority of the hairs of the victim represent a thorough and complete accord with the hairs found on the defendant that there exists no technical ground opposite to looking at the hairs found on the defendant as being the hairs of the victim..However, the hairs found on the defendant do not possess any so pronounced peculiarities or individualities that no one with certainty has the right to assert that they must have originated from the head of the victim"

General Acceptance

- Paul Kirk conducted some of the first studies on the potential forensic application of microscopical comparison of hair in the US (Gamble and Kirk 1941, Greenwell et al. 1941, Kirk 1940)
  - In addition to his publications on the microscopic characteristics of hairs, he conducted hair comparison studies with his students.
  - All of his students were required to compare a single hair to 20 known samples, where all the known samples were of a similar color and from individuals of a similar age.
  - As reported in his 1940 publication, no student who completed the routine failed to report the association correctly.

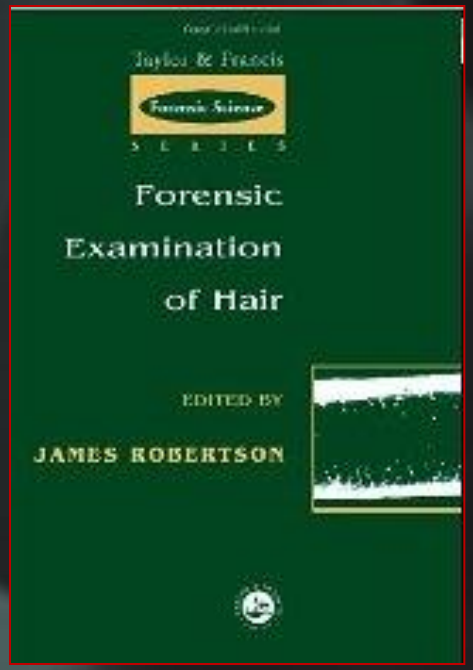


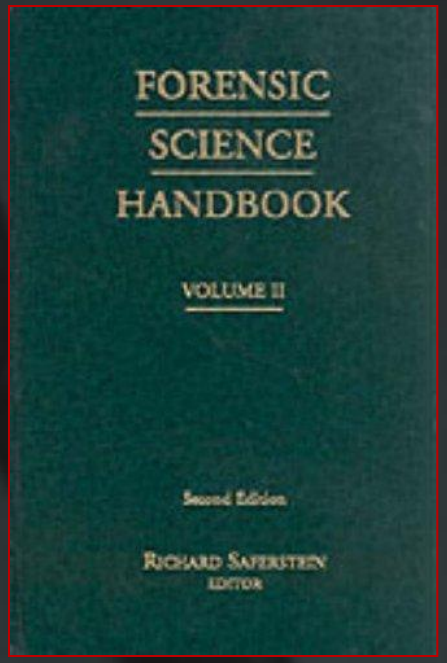
General Acceptance

- Animal hair identification is not employed solely by forensic scientists. It is an important tool used by wildlife biologists, archeologists, anthropologists, and textile conservators.
- Many researchers have investigated the morphological characteristics of animal hairs (Appleyard 1960, Day 1966, Mathiak 1938, Mayer 1952, Moore 1974, Oyer 1939, Stains 1958, 1962, Suzanski 1988, 1989, Wildman 1954, 1961, Williams 1938). These studies have aided in ecological studies, food-habit studies, and law enforcement investigations by providing descriptions, keys and photographs of the microscopic characteristics of animal hairs.

General Acceptance

The forensic comparison of hair is a generally accepted practice based on literature in the previously described peer-reviewed journals and in forensic text books including: Bisbing 1982, Deedrick and Koch 2004b, Hicks 1977, Kirk 1953, DeForest, et al. 1983, Moore 1974, Robertson 1999, Saferstein 1995, Seta 1988





References

References used in this presentation can be found in the SWGMAT Hair Bibliography posted on the SWGMAT website.