The Vital Role of Microscopes in Forensic Science

A microscope makes small objects look larger. Microscopes are essential tools in forensic science because they allow scientists to see and analyze tiny pieces of evidence. The term “microscope” originates from the

Latin “Microscopium,” which itself is rooted in the Greek words “mikros” (small) and “skopein” (to observe). This helps solve crimes by providing important details that can link suspects to crime scenes, identify substances, and compare different samples. Forensic science has relied heavily on microscopy since the beginning of this century. E. Locard established the practical and theoretical foundations of microscopic examination of trace amounts of evidence in 1928. In 1595, Hans Janssen, a Dutch spectacle maker, and his son Zacharias invented the first compound microscope.In 1665, Robert Hooke published Micrographia, which showed amazing studies of living things seen and drawn using a microscope.

Microscopes are tubes that have lenses and curved glass that bend light rays that pass through them. The most basic microscope is a magnifying glass with a single convex lens, which typically magnifies by 5-10 times. Most compound microscopes can magnify by 10, 20, 40, or 100 times, though professional ones can magnify by 1000 times or more.

There is a whole world of tiny, microscopic organisms and structures that remain invisible to us. To explore and discover this microscopic world, we need a powerful tool – a microscope. Microscopes are used to view specimens that are relatively very small in size, They are used to view the cellular structures of organs, germs, and bacteria. They play a vital role in the laboratory for the tissues and organisms that are too small to be seen clearly with the naked eye. Using a Microscope, scientists can make accurate measurements, quantify the size and shape of particles or cells, and study chemical reactions and physical phenomena under controlled conditions.

We are aware that a microscope is the only option. A magnifying glass is an alternative, but a microscope provides the correct result compared to a magnifying glass. Magnifying glasses are double-convex lenses and are used to make objects appear larger, but a microscope provides us with the correct result. Whenever we go to a crime scene, we find micro evidence (hair and threads). To view them, we need a magnifying glass, but for more analysis, we need a microscope.

In forensics, evidence is examined to solve crimes and aid in legal matters. The scale of evidence can vary from macro to micro, the microscopes play a crucial role in examining micro-evidence. Analyzing micro evidence like trace evidence (small fibers, glass fragments, paint chips), biological evidence (blood sample, saliva sample, etc.), and gunshot residue is possible through a microscope. Detailed analysis of evidence that is not visible to the naked eye is provided by microscopes, which are invaluable tools in forensic science. Both macro and micro evidence can be examined by forensic scientists to uncover crucial information that helps

solve crimes and bring justice. For example, the unique patterns on a piece of hair can help identify a person, or the specific type of pollen on a suspect's clothing can link them to a crime scene. These microscopic details can be seen and analyzed by microscopes, which can be valuable in solving crimes.

Microscopic analysis has a significant advantage in forensic investigations, as it allows scientists to uncover crucial clues, evidence, and traces that would otherwise be invisible to the naked eye. Microscopes can magnify tiny details up to thousands of times, revealing minute features and structures that are crucial for analysis. Using microscopic analysis, it is possible to distinguish between synthetic and natural fibers, identify dye composition, and correlate fibers found in crime scenes with those found on suspects. Microscopes can determine the species, racial origin, body area, and even some individual characteristics of hair samples. Microscopes allow for the detailed study of cells in blood, semen, saliva, and other bodily fluids, facilitating DNA extraction and profiling. Microscopes can detect differences in ink composition, paper fibers, and printing techniques, helping to identify forgeries and alterations.

"Trace evidence" refers to physical evidence that is small and transfers as a result of interaction between objects and individuals. These tiny fragments can include fibers, hair, soil, glass particles, paint chips, and even pollen. Trace evidence plays a critical role in forensic investigations due to its potential to link suspects, victims, and crime scenes. Because of their small size, trace evidence often requires microscopic analysis to reveal crucial details that can aid in solving crimes. Microscopes help forensic scientists identify the composition and origin of trace evidence. For instance, by examining fibers under a microscope, experts can determine if they came from a specific type of fabric. Similarly, hair samples can be analyzed to identify their human or animal origin and even match them to a specific individual through DNA analysis. Trace evidence analysis is aimed at identifying, comparing, and individualizing the source of evidence to help in crime scene reconstruction. Most commonly, the trace evidence that is examined is microscopic because it cannot be examined by the naked eye.

Types of microscopes used in forensic science:

- Light Microscope (Compound Microscope): Utilizes light and glass lenses to magnify tiny objects. It is used to examine blood cells, hair, fibers, and small tissue samples. The light microscope is a valuable tool for initially screening and analyzing biological evidence, particularly when color, speed, or live observation are crucial. Observing living cells, sperm motility, or fresh biological fluids can be done under a cover slip.
- Stereomicroscope (Dissecting Microscope): Gives a 3D view of things at a lower magnification level. It has the ability to magnify up to 100 times. Examining larger pieces of evidence, such as insects, bullets, tool marks, and fibers. Often used in forensic entomology to examine maggots or insect larvae on decomposed bodies. With its longer working distance (the space between the lens and the sample), forensic analysts can work with larger or more complex samples.

- Scanning Electron Microscope (SEM): Displays extremely detailed images of surfaces by utilizing electrons instead of light. It's capable of magnifying more than 100,000 times. SEM is particularly beneficial for forensic investigations that require surface detail at the microscopic to nanoscale, including gunshot residue, paint chips, glass fragments, and fiber topography. SEM can be coupled with an EDX [Energy Dispersive X-ray Spectroscopy] system, which allows elemental analysis of materials, useful for identifying the composition of trace evidence like glass or metal fragments.
- Comparison Microscope: Combines two microscopes to compare two samples at the same time. The purpose of this is to compare bullets, tool marks, hair, or handwriting to identify matches between a suspect and evidence. Offering simultaneous viewing eliminates the need to switch between two different images, leading to easier identification of minute differences or similarities between samples. It's specifically designed for forensic purposes, where direct comparison of evidence from a crime scene with suspect samples is essential.
- Polarizing Microscope: Studying materials that react to light in particular ways is done through the use of polarized light. Used for identifying fibers, minerals, and crystals, especially helpful in trace evidence. It reveals birefringence, refractive indices, and interference colors. Allows forensic scientists to determine crystal angles and grain orientation, useful in geology or explosives analysis.

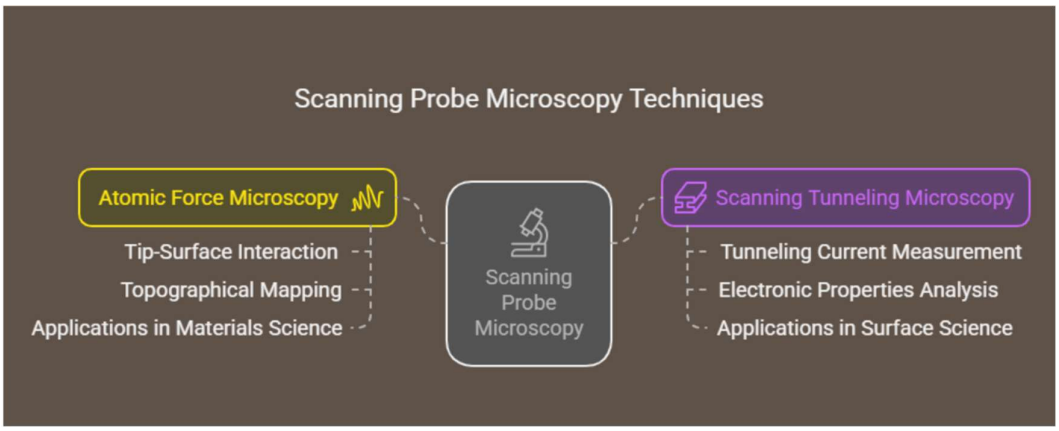
Microscopes play a crucial role in the daily work of forensic experts. Forensic experts use microscopes to examine tiny pieces of evidence such as hair, fibers, glass fragments, and paint chips. By magnifying these tiny traces, they can see details that are not visible to the naked eye, like the unique patterns on a fiber or the tiny scales on a hair strand. This helps them match evidence to a suspect or a location. Forensic experts use microscopes to analyze handwriting, ink, paper fibers, and printing techniques to identify forgeries, alterations, or the source of a document. Forensic entomologists use microscopes to study insects found on decomposing bodies. Microscopes are utilized by forensic microbiologists to examine bacteria, fungi, and other microorganisms that can provide clues about the time of death, location of a crime, or sources of contamination. The microscope's capacity to reveal these hidden details is a crucial tool for a forensic expert's daily work, enabling them to uncover the truth and solve cases.

Recent advancements in microscopy used in forensic science

- Super-Resolution Microscopy (SRM): A special type of microscope that can zoom in much more than regular microscopes. It can show extremely tiny details, down to the nanometer level. Helps experts see very small traces of evidence, like fibers, cells, or particles that normal microscopes can’t detect.
- Digital Holographic Microscopy (DHM): A method that creates 3D images of very small objects. It can look at complex or layered materials without damaging them. Great for studying things like tissue samples or layered materials (e.g., paint, hair), giving a full and undamaged view of the evidence.
- Fluorescence Lifetime Imaging Microscopy (FLIM): A microscope that measures how long fluorescent light stays in a sample. Can tell apart different biological substances (like blood, saliva, or

tissue), and helps identify specific chemicals at crime scenes. Shows differences in the molecular structure of materials.

- Scanning Probe Microscopy (SPM): A group of methods that use a tiny probe to "feel" the surface of a sample.



The use of microscopes enables forensic scientists to examine small evidence like hair, fibers, paint chips, and glass fragments. This detailed analysis can help link a suspect to a crime scene or victim. The use of comparison microscopes allows for the comparison of bullet striations and shell casings, which can aid in the identification of the firearm used in a crime. The use of microscopes is to examine unknown substances and determine whether they are illegal drugs or other controlled substances. In cases where microelectronic devices are tampered, microscopes can be used to examine the internal components for signs of alteration or damage. The use of microscopes is beneficial in examining residues from fire and explosion scenes to identify explosive materials.

Real-life forensic cases where microscopy was pivotal

- Soni Kumar @ Soni Rajak vs The State of Bihar on 4 November, 2015

On December 28, 2002, three students (Vikas Ranjan, Prashant Singh, and Himanshu Yadav) had a dispute with a phone booth owner at Sammelan Market, Patna. After an argument over a bill, they were beaten by the shopkeeper and other shop owners, then locked inside the market.

Police arrived and, according to the prosecution, shot the three students dead in a fake encounter, falsely claiming the students were criminals who fired at the police first. The students were also beaten by a mob after being shot.

The case was investigated by the CBI, which found the students were innocent and the encounter was staged. In 2014, a fast-track court convicted the main police officer (Shamshey Alam) and others, giving Alam the death penalty and others, including constable Arun Kumar Singh, life imprisonment.

The court accepted the forensic report, which said that the deformed bullet found in the victim's body and the three empty cartridges found at the scene were fired from the same pistol surrendered by Accused No. 1 (Shamshey Alam). This conclusion was reached by experts using a comparison microscope.

Role of the Comparison microscope:

A comparison microscope was used to closely look at marks made on bullets and cartridges. Every gun leaves unique marks (like a fingerprint) on bullets when it fires. The experts compared the test-fired bullets and cartridges with the evidence bullets and cartridges. Since the marks matched, they concluded that all were fired from the same pistol.

- The Atlanta Child Murders (USA, 1979–1981)

Between 1979 and 1981, about 29 Black children and young adults were murdered in Atlanta. The community was terrified, and the police struggled to find the killer. In 1981, Wayne Williams, a young man from Atlanta, was stopped by police near a bridge where bodies had been found. Soon after, more bodies appeared nearby, and Williams became the main suspect. Police found fibers from Williams' home and car on two of the victims, and he failed a lie detector test. He was arrested and later convicted of killing two of the victims, but he was never officially found guilty for the rest of the murders. Some people, including relatives of the victims, believe Williams is innocent and was used as a scapegoat to close the case quickly. There are also claims that evidence pointing to other suspects, like members of the Ku Klux Klan, was hidden to prevent racial tensions. In February 1982, Wayne Williams was convicted of the murders of Nathaniel Cater and Jimmy Ray Payne. He was sentenced to two life sentences. Although police believed he was responsible for most of the Atlanta Child Murders, he was only officially convicted of these two. Many other cases remain unsolved. This conclusion was reached by experts using a comparison microscope.

Role of the Comparison microscope:

Microscopes were used to analyze fibers and hairs found on the victims' bodies. Investigators collected fibers from Williams' home, car, and family dog. Under the microscope, they compared these fibers to those found on the victims. The fibers from Williams' environment (carpet, dog hair, etc.) matched the fibers found on the victims. This microscopic evidence was a key part of the case against Williams, since it linked the victims to him when other evidence was weak.

In conclusion, microscopes play a vital role in forensic science by providing detailed insights into microscopic evidence like fibers, hairs, and particles. They help investigators link suspects to crime scenes, identify materials, and preserve evidence accurately. Continual advancements in microscopy technology enhance forensic capabilities, ensuring thorough and precise analysis that supports investigations and contributes to justice being served.

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Shravanee is known for her brilliance, dedication, and an innate passion for forensic science. Hardworking and always eager to learn more, she approaches every challenge with focus and determination. For her, forensic science is not just a subject, it's a natural instinct. Her curiosity, precision, and consistent academic excellence make her standout and a true inspiration to her peers.