

## UNIT – I - Forensic biotechnology

**Forensic biotechnology** uses advanced biological and genetic techniques to analyze evidence like DNA, blood, hair, and saliva for criminal investigations, helping identify suspects, exonerate the innocent, establish paternity, and even solve historical crimes by matching genetic profiles to link individuals to crime scenes or verify identities. It applies molecular biology, genetics, and genomics to interpret biological clues, extending beyond traditional DNA fingerprinting to include microbial forensics and proteomics, providing powerful tools for justice.

### Scope of Forensic Science

- **Criminal Investigations:** Analyzing evidence (DNA, fingerprints, ballistics, digital data) to identify suspects, reconstruct events, and link parties.
- **Specialized Fields:** Includes Criminology, Toxicology, Pathology, Anthropology, Questioned Documents, Digital Forensics, and Wildlife Forensics.
- **Beyond Crime:** Also addresses civil disputes, environmental crimes (pollution), product failures, and mass disasters (collapses, derailments).
- **Legal Context:** Provides objective, scientific data for criminal justice, ensuring fairness by proving guilt or innocence.
- **Tools & Techniques:** Fingerprint analysis, DNA profiling, ballistics, trace evidence analysis (hair, fibers, paint), drug testing, and digital analysis.

### Applications & Techniques

- **DNA Profiling/Fingerprinting:** The core technique, creating unique genetic profiles from crime scene samples (blood, semen, skin) to match suspects.
- **PCR (Polymerase Chain Reaction):** Amplifies tiny amounts of DNA for analysis, crucial for degraded samples.
- **Mitochondrial DNA (mtDNA) & Y-Chromosome Analysis:** Used for identifying individuals from old, damaged samples or tracing paternal lineage.
- **Forensic Genetics:** Studies genetic markers (STRs, VNTRs) that vary between people for identification.
- **Microbial Forensics:** Identifies microorganisms to determine origins, timelines, or biocrimes.
- **Forensic Proteomics:** Analyzes proteins in samples for deeper insights.
- **Toxicology:** Detects drugs, poisons, and toxins in biological specimens.

### History and Development

Forensic biotechnology evolved from early biological forensics (blood typing, serology) into modern DNA analysis, revolutionized by Alec Jeffreys's DNA fingerprinting (1984) and Kary Mullis's PCR (1983), enabling trace DNA analysis, solving cold cases, and creating DNA databases (like the UK's

1995 and FBI's 1998 systems). Key milestones include blood grouping (Landsteiner, 1901), DNA profiling's first criminal use (1986), and advancements in PCR for DNA amplification, shifting forensics from macroscopic to microscopic biological markers for powerful individual identification.

## **Ancient Roots of Forensic Science**

### **1. Forensic Science in Ancient China**

Forensic science's roots can be traced back to ancient civilizations. During the 6th century in China, a writer named Song Ci, who was also regarded as the father of forensic science, wrote a book titled "Xi Yuan Lu," or "The Washing Away of Wrongs." This book covered methods that distinguished accidental deaths from homicides and offered guidance on examining wounds and determining causes of death. Song Ci's work marked one of the earliest documented uses of forensic principles in criminal cases.

### **2. The Role of Forensic Techniques in Ancient Rome**

In ancient Rome, forensic methods were also used, but in rudimentary forms. Roman courts required evidence in public disputes, and persuasive speakers played a role in arguing cases. Methods such as analyzing bloodstains, footprints, and handwriting were used at the foundational level to link suspects to crimes and demonstrated the initial or early understanding of people for solving crimes.

## **The Rise of Forensic Science in the 19th Century**

### **1. The Bertillon System**

In the late 19th century, Alphonse Bertillon, a French police officer, introduced a system called anthropometry, which measured physical characteristics to identify criminals. In the Bertillon system, the length of the arms, the size of the head, and other unique body features were used for measurements. This method laid the foundation for modern forensic identification methods, though it was eventually replaced by fingerprinting.

### **2. The Introduction of Fingerprinting**

In the 1890s, extensive research was conducted by Sir Francis Galton, an English scientist, on fingerprints. He concluded that each fingerprint is unique and permanent. His work led to the adoption of fingerprints as a reliable form of identification, and by the early 20th century, fingerprinting was widely accepted in criminal investigations. This advancement helped law enforcement link individuals to crime scenes with better accuracy.

### **3. Toxicology and Forensic Chemistry**

In 1836, the English chemist James Marsh developed a method for detecting arsenic in the body, an early example of forensic toxicology. This proved to be a breakthrough and provided investigators with the tools to examine chemical traces in the human body. This revolutionized the way to determine

the causes of death. Since then, toxicology has become a fundamental aspect of modern forensic science, with applications in autopsy investigations, drug testing, and environmental analysis.

## **The 20th Century: Forensic Science Takes Major Strides**

The 20th century saw tremendous growth and formalization in forensic science, establishing it as a critical tool for justice systems worldwide.

### **1. Establishment of Crime Labs**

In 1910, Edmond Locard, a French criminologist, founded one of the first forensic laboratories in Lyon, France. Known for his famous "Locard's Exchange Principle"—the idea that "every contact leaves a trace"—Locard emphasized that criminals unknowingly leave traces of evidence at crime scenes. This principle became a basis in forensic investigations, leading to the development of crime laboratories around the world.

### **2. Forensic Pathology and Autopsy Practices**

Forensic pathology also witnessed significant advancements during the 20th century. Autopsies became a crucial tool to investigate suspicious deaths, with specialists examining bodies to determine causes of death, injury patterns, and times of death. These advancements laid the foundation for modern practices in homicide investigation, helping to uncover critical details that lead to solving cases.

### **3. Development of Ballistics and Firearms Analysis**

In 1925, Calvin Goddard, an American forensic scientist, pioneered ballistics, the study of firearms, bullets, and cartridge cases. Goddard's work allowed investigators to match bullets to specific firearms by examining unique striations, or grooves, left on a bullet's surface. Ballistics to date are essential in investigating crimes involving firearms, assisting law enforcement in linking weapons to specific incidents.

## **Modern Advances in Forensic Science**

The latter part of the 20th century and the early 21st century introduced remarkable technological innovations that transformed forensic science.

### **1. DNA Profiling: A Breakthrough in Identification**

One of the most significant breakthroughs in modern forensic science came with the discovery of DNA profiling in the 1980s. Developed by Dr. Alec Jeffreys, DNA profiling uses genetic material to identify individuals with extraordinary accuracy. It was first used in a criminal case in 1986, and since then, it has become one of the most powerful tools in forensic investigations, solving cold cases, exonerating the innocent, and confirming identities.

### **2. Digital Forensics: Solving Crimes in the Digital Age**

With the advancement in technology, the need for digital forensic methods to investigate cyber crimes has also risen. Digital forensics involves recovering, analyzing, and interpreting data from electronic devices like computers, smartphones, networks, and other digital devices. It helps in cases involving cyber-attacks, fraud, and identity theft. With the rise of the internet and social media, digital forensics continues to evolve rapidly, adapting to new challenges in digital evidence management.

### 3. Advances in Forensic Imaging and Virtual Autopsies

Forensic imaging technologies such as CT scans and MRIs have also become valuable tools. Virtual autopsies use these imaging techniques to examine bodies non-invasively and provide detailed views of internal injuries and conditions. This advancement is particularly useful in preserving evidence and offering additional insights when conventional autopsy methods are not feasible.

#### Early Biological Forensics (Pre-1980s)

- **Ancient Roots:** Early methods used insects (flies on blood) and body features (odontology) for clues.
- **Blood Typing (1901):** Karl Landsteiner discovered ABO blood groups, making blood a key forensic tool.
- **Serology Advancements (1915-1970s):** Leone Lattes developed methods for dried bloodstains; later, enzyme (like PGM) and protein (MNSs, Rh) variations were used.
- **Anthropometry (Late 1800s):** Alphonse Bertillon used body measurements for identification before fingerprints became standard.

#### The DNA Revolution (1980s-1990s)

- **DNA Fingerprinting (1984):** Alec Jeffreys invented DNA profiling (using Variable Number Tandem Repeats or VNTRs) for unique identification.
- **PCR (1983):** Kary Mullis developed Polymerase Chain Reaction, allowing tiny DNA samples (like hair, saliva) to be amplified for analysis.
- **First Applications (1986-1987):** DNA profiling was first used in the UK to convict Colin Pitchfork in rape-murders; PCR-based DNA testing followed.
- **Databases & Standards (1990s):** The UK established the first national DNA database (1995), followed by the FBI's CODIS (1998).

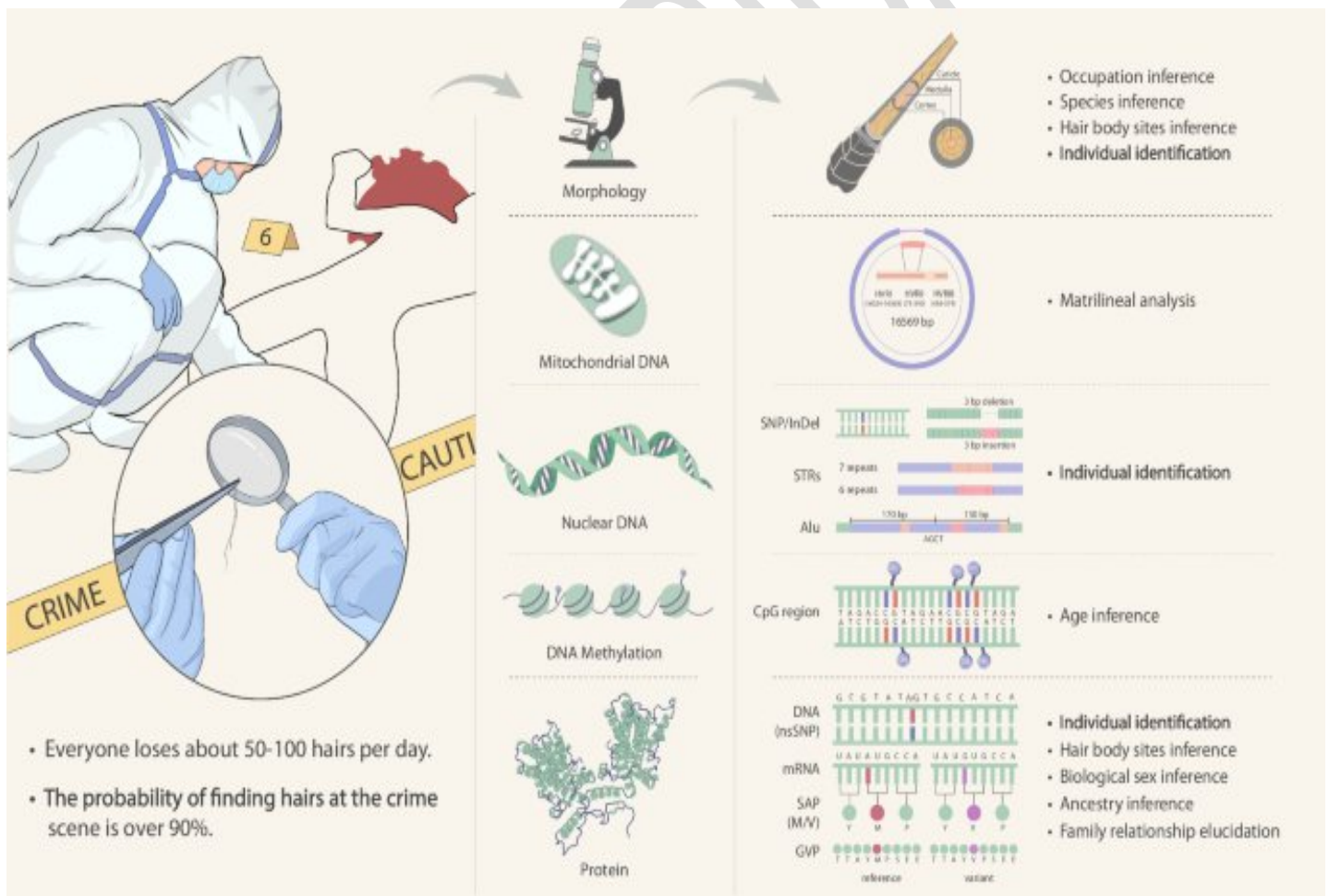
#### Modern Developments (2000s-Present)

- **Short Tandem Repeats (STRs):** Became the standard for DNA profiling, offering high discrimination power.
- **Mitochondrial DNA (mtDNA):** Used for degraded samples (e.g., old bones, hair shafts) where nuclear DNA is scarce, writes the University of California, Berkeley's Understanding Science.

- **Rapid DNA & Field Testing:** Technologies enabling quick analysis at crime scenes or police stations.
- **Forensic Genetics:** Advancements in SNP (Single Nucleotide Polymorphism) analysis for ancestry inference and identifying traits.
- **AI & Automation:** Artificial Intelligence aids in fingerprint analysis, bloodstain pattern analysis, and digital forensics.

## Forensic genetics

**Forensic genetics** is the science of analyzing DNA from biological evidence (blood, saliva, hair, etc.) to identify individuals, link suspects to crimes, establish paternity, and identify disaster victims, using markers like STRs (Short Tandem Repeats) and SNPs (Single Nucleotide Polymorphisms) to create unique genetic profiles (DNA fingerprints) for legal purposes. It has evolved from older methods to advanced sequencing, enabling prediction of traits (eye/hair color), ancestry, and even lifestyle habits, with techniques like Massively Parallel Sequencing (MPS) and Forensic Genetic Genealogy (FGG) expanding its investigative power.



The field evolved significantly after the discovery of DNA fingerprinting by Sir Alec Jeffreys in 1985, which revolutionized forensic science. Today, forensic genetics relies on advanced techniques like STR profiling, mitochondrial DNA sequencing, Y-chromosome analysis, and next-generation sequencing.

### Principles & Applications

- **Individual Identification:** Creating unique DNA profiles from samples found at crime scenes (blood, semen, skin).
- **Relationship Testing:** Establishing biological links, like parentage, for legal or personal reasons.
- **Criminal Investigations:** Connecting suspects to evidence, linking crimes, and searching DNA databases (like CODIS).
- **Victim Identification:** Identifying victims of mass disasters or human remains.
- **Phenotyping & Ancestry:** Inferring physical traits (eye/hair color, body composition) and biogeographic ancestry from DNA.

### Technologies & Markers

- **Short Tandem Repeats (STRs):** Highly variable, short DNA sequences used for standard profiling.
- **Single Nucleotide Polymorphisms (SNPs):** Variations at single DNA positions, useful for ancestry and trait prediction.
- **Mitochondrial DNA (mtDNA):** Analyzed from old or degraded samples, inherited maternally.
- **Next-Generation Sequencing (NGS/MPS):** Allows analysis of thousands of markers simultaneously, providing more comprehensive profiles and new data.
- **Forensic Genetic Genealogy (FGG):** Uses public genealogy databases to find distant relatives of unknown DNA donors, narrowing down suspects.

### Evolution & Future Trends

- **From VNTRs to MPS:** Evolved from older Variable Number Tandem Repeats (VNTRs) to more efficient PCR-based methods (like DQ alpha) and now to NGS.
- **Omics Era:** Expanding to incorporate RNA, DNA methylation, and microbiome analysis (e.g., genital microbiomes) for richer information.
- **AI & Machine Learning:** Integration of AI for complex mixture interpretation and data analysis.
- **Environmental DNA (eDNA):** Detecting DNA from surfaces or air to identify people present in a location.

### Forensic agriculture

**Forensic agriculture**, a lesser-known but increasingly important branch of forensic science, is the application of agricultural knowledge and techniques to solve crimes and answer questions related to crop production, environmental damage, and food security.

- Forensic agriculture is a specialized field that applies scientific principles of agriculture to legal investigations involving crops, soils, pests, livestock, and environmental impacts.
- It focuses on examining agricultural materials—such as seeds, soil samples, plant residues, fertilizers, pesticides, and even genetic fingerprints of crops—to determine their origin, authenticity, and any tampering or malpractice. This discipline helps in uncovering agricultural crimes such as crop theft, food adulteration, illegal pesticide use, contamination of farmland, and disputes over land use or crop damage.
- Forensic agricultural experts often use techniques from soil science, plant pathology, entomology, microbiology, genetics, and chemistry to analyze evidence. For example, soil profiling can link a suspect or vehicle to a specific field based on mineral composition and organic matter content, while DNA barcoding can identify plant varieties involved in seed fraud or genetic modification disputes.
- Pesticide residue analysis helps determine whether chemicals were applied legally or excessively, and plant disease diagnostics can reveal whether crop losses were natural or deliberately induced.
- Forensic agriculture also plays a crucial role in environmental monitoring by detecting pollution from agricultural runoff, identifying sources of contamination, and supporting compliance with environmental regulations. Overall, the field blends agricultural knowledge with investigative methods to ensure food safety, protect farmers' rights, resolve legal conflicts, and support sustainable agricultural practices.

### Areas & Applications

- **Food Fraud & Authenticity:** Verifying "organic" claims or identifying adulterated products like honey or olive oil.
- **Crop & Livestock Investigation:** Identifying the root cause of large-scale crop losses, disease outbreaks (using AI & microbiome analysis), or animal health issues.
- **Environmental Forensics:** Analyzing soil and water for contamination from pesticides or other pollutants.
- **Criminal Investigations:** Using plant evidence (pollen, seeds, leaves) for forensic botany to link suspects to crime scenes or track illicit drug cultivation.
- **Traceability:** DNA fingerprinting and barcoding to trace the origin of commercial agricultural products.
- **Machinery & Equipment Faults:** Investigating failures in farm equipment or storage systems.

### Techniques Used

- ✓ **Chemical Analysis:** Testing for contaminants in soil or products.
- ✓ **Genetic Testing:** DNA analysis for identification and traceability.
- ✓ **Remote Sensing & AI:** Satellite data and AI for disease prediction and large-scale monitoring.

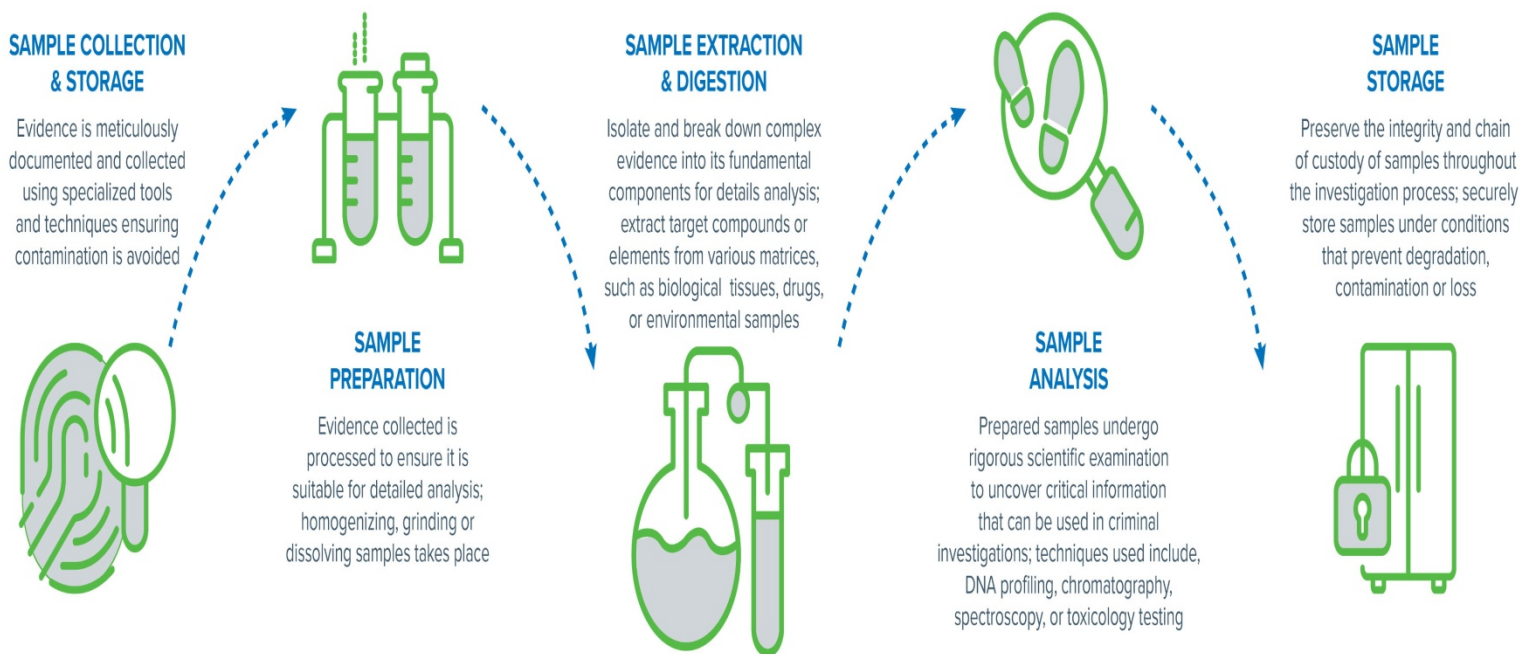
- ✓ **Microbiology:** Analyzing soil/plant microbiomes to find pathogens.
- ✓ **Forensic Entomology:** Studying insects on remains or crops for timing and location.

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## UNIT – II

### Crime Scene Investigation

In forensic biotechnology, crime scene investigation begins with a systematic and scientific approach to locating, documenting, and securing biological and trace evidence that may help reconstruct events or identify individuals involved in a crime. Investigators first establish a secure perimeter to prevent contamination, followed by detailed observation, photography, sketching, and recording of the scene. Biological materials such as bloodstains, hair, saliva, tissue fragments, and other organic residues are identified using visual examination, alternate light sources, or presumptive tests. The integrity of the scene must be maintained at all times to ensure that collected evidence remains admissible in court.



### Collection & Preservation

- **Minimize Contamination:** Use clean tools (forceps), wear gloves, and avoid touching evidence directly.
- **Biologicals (Blood, Saliva, Semen):** Air-dry stains in the shade (not sun/heat) to prevent cell damage and bacterial growth.
- **Trace Evidence (Hairs, Fibers):** Collect with forceps onto trace paper, then fold into an envelope; don't remove fibers stuck to items, package the item itself.
- **DNA Samples:** Must be handled carefully; tiny amounts are sufficient for PCR analysis.
- **Digital Evidence:** Specific protocols are followed for phones, computers, etc..

### **Packaging (Protecting Biotech Potential)**

- **Separate & Secure:** Each item/sample gets its own container (paper bags/envelopes for biologicals; boxes for firearms/sharp objects) to prevent mixing and damage.
- **Air-Permeable:** Paper bags are ideal for biologicals; plastic bags cause moisture buildup and degrade DNA.
- **Protect from Shock:** Use cotton or thermocol in boxes for fragile items like bullets.
- **Fingerprints:** Package so packaging doesn't touch the print surface.

### **Forwarding & Documentation (Chain of Custody)**

- **Labeling:** Mark each package clearly with case number, item description, date, collector's initials, and location.
- **Sealing:** Seal packages with tape and initial across the seal to show tampering.
- **Chain of Custody Log:** Document every person who handles the evidence from collection to lab analysis, ensuring accountability.

### **Applications**

- **DNA Analysis:** Proper handling preserves the DNA profile, allowing powerful techniques like PCR to amplify tiny samples for identification.
- **Admissibility:** A perfect chain of custody and careful packaging proves evidence wasn't altered, making it admissible in court.

### **Collection of Physical and Trace Evidence**

Evidence collection in forensic biotechnology requires precision and sterile techniques to avoid cross-contamination.

- Physical evidence includes visible materials like biological tissues, weapons with biological residues, or bodily fluids, while trace evidence consists of microscopic materials such as DNA-containing skin cells, fibers, soil particles, pollen, and microbial signatures.
- Each piece of evidence is collected using appropriate tools such as sterile swabs, tweezers, scalpels, tape lifts, or vacuum devices depending on the type of material.
- Investigators must wear gloves, masks, and protective clothing and frequently change equipment to maintain sample purity.

### **Preservation of Evidence**

Proper preservation is essential to prevent degradation of biological materials, which are often sensitive to heat, moisture, and microbial growth. Wet biological samples like blood or saliva must be air-dried before packaging, while tissues or DNA samples may require refrigeration or freezing to prevent enzymatic breakdown.

- Trace evidence such as fibers, hair, or soil is stored in clean, dry containers to maintain its integrity.
- Chemical preservatives or buffers may be used for specific samples, such as swabs placed in DNA-stabilizing solutions, to ensure long-term viability for molecular analysis.

### **Packing and Forwarding of Evidence**

Evidence must be packed in suitable containers to ensure safety, prevent contamination, and allow proper airflow where needed.

- Paper bags, envelopes, and cardboard boxes are used for moist biological samples to avoid mold growth, while sealed plastic containers are appropriate for dry materials.
- Each package must be clearly labeled with case details, collection time, location, and the collector's identification.
- Chain-of-custody forms accompany all evidence, documenting every individual who handles the samples from the crime scene to the forensic laboratory.
- Secure transportation ensures that samples arrive intact, enabling accurate analysis using DNA profiling, PCR, sequencing, and other biotechnology-based methods essential for linking suspects, victims, and crime events.

### **Questioned Documents**

In forensic biotechnology, the examination of questioned documents involves the scientific analysis of written or printed materials to verify their authenticity, origin, or alterations that may indicate criminal activity.

- These documents may include handwritten notes, signatures, contracts, wills, cheques, or identification papers suspected to be forged or tampered with.
- Experts use a combination of visual inspection, microscopy, spectroscopy, and digital enhancement techniques to study the physical and chemical properties of inks, papers, and writing patterns, enabling accurate detection of inconsistencies or fraudulent modifications.

### **Identification of Handwriting**

Handwriting identification focuses on comparing questioned writing with known samples to determine whether they were created by the same individual.

- Investigators analyze various characteristics such as letter formation, slant, spacing, pressure, rhythm, speed of writing, and unique individual habits.
- While handwriting can naturally vary, each person has specific patterns known as "individuality traits" that remain consistent across samples.
- Advanced tools such as image analysis software and biometric handwriting recognition systems support forensic experts in making precise comparisons, improving objectivity and reliability.

## Identification of Signature

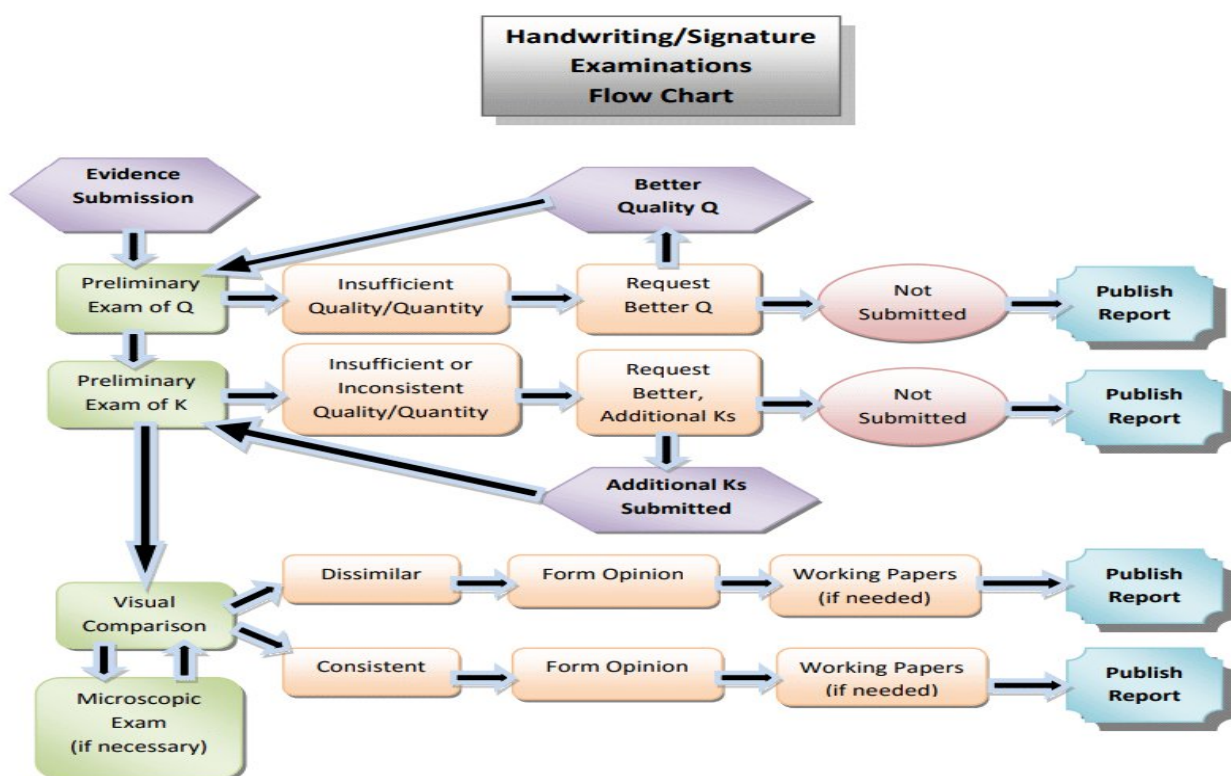
Signature examination is crucial because signatures are widely used to authorize legal and financial documents.

- Forensic document analysts study elements such as line quality, pen lifts, connecting strokes, alignment, fluency, and overall style.
- Genuine signatures usually show smooth, confident movements, while forged ones may exhibit tremors, blunt starts and stops, uneven pressure, or tracing marks.
- High-resolution scanners and infrared or ultraviolet light may be used to identify alterations, overwriting, or disguised writing, helping determine whether the signature is authentic or fraudulent.

## Detection of Forgery

Forgery detection involves identifying intentional alterations or fabrications made to deceive, ranging from simple modifications to sophisticated document fraud.

- Common types include signature forgery, traced writing, simulated handwriting, ink alterations, erasures, additions, and counterfeit printing.
- Examiners utilize tools such as stereomicroscopes, electrostatic detection apparatus (ESDA), chromatography for ink analysis, and spectral imaging to detect erasures, indentations, chemical changes, and hidden writing.
- Modern forensic biotechnology also integrates digital forensics to analyze scanned or electronically manipulated documents, ensuring comprehensive detection of fraud.
- Together, these techniques help establish the authenticity of documents and play a vital role in legal investigations and judicial proceedings.



## Areas of Examination

- ✓ **Handwriting & Signature Identification:** Comparing unique writing habits (strokes, spacing, alignment, pressure) from questioned samples to known samples, looking for natural variations versus deliberate disguise or forgery.
- ✓ **Forgery Detection:** Identifying alterations like erasures (chemical/mechanical), overwritings, additions, interpolations, or substitutions.
- ✓ **Ink Analysis:** Using techniques like chromatography and spectroscopy to differentiate inks, determine sequence of strokes, and identify ink composition.
- ✓ **Paper Analysis:** Examining paper type, fiber content, watermarks, and folds to assess origin and age.
- ✓ **Instrument Analysis:** Identifying typewriters, printers, rubber stamps, and other writing instruments.

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