Zig Zag Education

Science Cambridge Advanced National (AAQ)

Course Companion

Cambridge Advanced National in Applied Science

F185 Forensic science

Endorsed for Cambridge OCR qualifications

CAMBRIDGE OCR

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POD 12840

Contents

Sensitivity in teaching this resource is important as it deals with very sensitive content th
some students. It is vital that the teacher checks any content carefully beforehand to juc
particular some case studies contain references to potentially upsetting topics such as
and strangulation. In addition, some of the images in this resource are very graphic an
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these are viewed, along with any additional content you intend to use, **before** using them

It is the teacher's responsibility to ensure the safety of their students in the classroom. P
instructions carefully and are confident in your own knowledge b[illegible]re carrying out any o
suggested in this resource. If you are unsure about anythi[illegible]k advice before carrying

This resource is intended to supplem[illegible]aching only.

It is the teacher's respons[illegible]decide how to use this resource to assist themselves
You may simp[illegible]to read this material to better inform yourself and to help you pre
ideas for your [illegible]g. You may also consider whether it is appropriate to hand out sc
to use some of the activities for classwork and homework. You may also consider whet
the booklet to be worked through by your students more independently.

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Teacher's Introduction

This course companion has been written specifically for the Cambridge OCR Level 3 Alternative Academic Qualification Cambridge Advanced Nationals in Applied Science qualification (first teaching from September 2025).

The theory notes, examples and questions cover the essential knowledge and understanding prescribed in the optional Unit F185 specification for the Extended Certificate qualification.

About Unit F185: Forensic biology

Unit F185 (60 GLH) is centre assessed using four practical activities that learners carry out independently. Centre assessments are OCR moderated.

Unit F185 is an optional unit and will draw on learning from Unit F180 (Fundamentals of science) and Unit F181 (Science in society).

The resources is divided into four sections, with the aim of providing the students with the information in the order in which it will be most useful to them as they complete the tasks of the assignment. Specification references have been provided in brackets.

Within each section there are student notes covering the specification content and structure. These notes include descriptions of theory, supported with examples and diagrams where appropriate.

Remember!

Always check the exam board website for new information, including changes to the specification and sample assessment material.

Questions are interspersed throughout the guide to assess and develop understanding. There are recall questions to check knowledge understanding, more creative your turn tasks, and tasks which allow students to apply their knowledge. Additionally, there are formative discussion questions, based around a practice scenario to allow students to practice key skills.

Sensitivity in teaching this resource is important as it deals with very sensitive content that may be upsetting or difficult for some students. It is vital that the teacher checks any content carefully beforehand to judge its suitability for their class. **In particular some case studies contain references to potentially upsetting topics such as murder, serial killers, rape, death and strangulation. In addition, some of the images in this resource are very graphic and may upset some students – in particular Figure 1.4 on page 7 which contains images of rigor mortis, livor mortis and pallor mortis.** Please ensure that these are viewed, along with any additional content you intend to use, **before** using them in class.

October 2025

Endorsement statement

The teaching content of this resource is endorsed by Cambridge OCR for use with
Level 3 Alternative Academic Qualification Cambridge Advanced National in Appli
(H151). All references to assessment, including assessment preparation and pract
format/style are the publisher's interpretation of the specification and are not en

This resource was designed for use with the version of th cification available
However, as specifications are updated over time th re ay be contradictions be
specification, therefore please use the ir ion on the latest specification and
all times to ensure students ar f my prepared for their assessments.

Endorseme ca t a resource is suitable to support delivery of a Cambri
does not m t the endorsed resource is the only suitable resource to suppor
or necessary to achieve the qualification.

Cambridge OCR recommends that teachers consider using a range of teaching an
their own professional judgement for their students' needs. For more information
process, please visit the Cambridge OCR website.

Who robbed the corner shop

This example will be referred to in the formative discussion question boxes throu

Scenario

A corner shop selling snacks, drinks and essential items was the scene of a robbe
10.43pm. It was a dark, rainy evening (see **Figure 0.1**).

A person wearing a black mask and holding a knife entered the store. They stole
register. They then fled the scene via the doored entrance to the shop. A custom
chased after the person as they left the shop. The attacker turned and stabbed th
Splatters of blood can be seen on the floor.

The attacker fled on a bicycle. An ambulance and police were then called to the s

The person was not wearing gloves and held the door handle to swing open the
getaway bike, they spat their chewing gum onto the pavement. A wet, muddy sh
the shop floor.

A bike, matching that described by the witness, was found ditched in a layby one
Hair and fibres were found present on the bike handlebars.

The police identify two suspects.

- **Suspect A:** Has a history of theft in the area and was spotted by an employe
shop. The police found muddy trainers by their front door, a pack of chewi
and a black ski balaclava (headwear that exposes only part of your face) hu
house. The police found a kitchen knife with a small trace of blood on it in t
suspect's home. The suspect said they had cut themselves on it when prep
- Police collect the following evidence from Suspect A: fingerprints, a sample
cultured sample from a shoe, a shoe print, fibres, hair, the balaclava, th
chewing gum.

- **Suspect B:** Was seen loitering outside the shop the day before. The suspect
employee as they shouted aggressively at them the previous week for refu
them without ID to confirm they were over 18 years old. The police find a b
of the suspect's home. The suspect said they had been cutting a joint of be
- Police collect the following evidence from Suspect B: fingerprints, a sample
a cultured soil sample from a shoe, a shoe print, fibres, hair, and the knife.

Figure 0.1 *A corner shop, like the one described in this exampl*

Forensic biology disciplines

Key points covered

- Defining forensic science
- Civil and criminal law
- Locard's exchange principle
- Differences between forensic science and forensic biology
- Serology
- Pathology
- Anthropology
- Odontology
- Botany
- Microbiology
- O
- E
- B
- T
- F
- Id

Features of forensic science and forensic biology (1.1.1)

Forensic science is the application of scientific methods and techniques to investigate crimes and examine **evidence** that might be presented in a court of law.

Forensic scientists work to uncover the truth by:

- Collecting evidence: This involves gathering physical evidence from crime scenes, such as fingerprints, **DNA**, blood, and other biological materials.
- Analysing evidence: In specialised laboratories, forensic scientists examine evidence using advanced techniques to identify substances, match samples, and determine the origin of materials.
- Interpreting results: Scientists analyse data obtained from the evidence and draw conclusions that can be used in legal proceedings.
- **Testifying** in court: Forensic scientists often provide expert testimony, explaining their findings to judges and juries in a clear and understandable m

Criminal and civil law

Table 1.1 shows the difference between criminal law and civil law:

Table 1.1 Differences between criminal law and civil law.

	Criminal law	
Primary goal	• In criminal cases, the primary goal is to determine guilt or innocence.	• Civil cases i individuals with the go or resolving
How forensic science is used	• Identifying **suspects**: DNA analysis, fingerprint matching, and other forensic techniques can link a suspect to a crime scene. • Establishing the crime: Forensic evidence can help prove that a crime occurred, such as determining the cause of death in a murder case. • Providing **corroborating evidence**: Forensic findings can support other forms of evidence, strengthening the prosecution's case.	• Determine reconstruct can analyse who was at • Authenticat document e authenticity important c

Suspect – someone ic have committed a crim
Liability – the legal re
Corroborate – to provid

	Criminal law	
Examples of forensic evidence	• **DNA profiles** matching a suspect to biological evidence • Ballistic analysis linking a firearm to a crime scene • Toxicology reports determining the cause of death	• Handwriting author of a • Accident re in a car acci • Fire investig investigate whether ins • Medical exp professiona on the exte potential lo

DNA profile – a pattern of DNA used to id... individual or a sample of bodily ...

Locard's ex...ge principle

Locard's exchange principle is a fundamental concept in forensic science, stating: '

This means that when two objects come into contact, there is an exchange of materials between them, as seen in **Figure 1.1**.

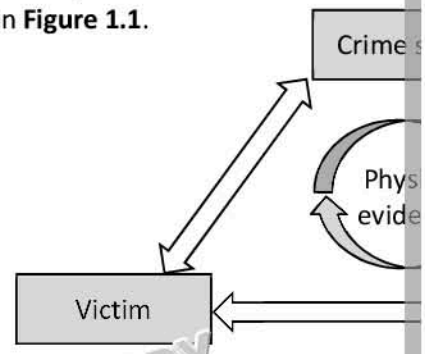

Figure 1 ... showing Locard's exchan...

The principle in action

This principle is the cornerstone of crime scene investigation. Whenever someone enters a crime scene, they bring something with them (like dirt, hair, skin cells or fibres from their clothing) and they also take something away with them (like fibres from the victim's clothing, or carpet fibres).

Examples of evidence left behind:

- Hair: from the victim, su... or others at the scene
- Skin cells: shed b... ...als
- Blood: f... ...victim or suspect
- DNA: fou... ...blood, saliva, hair, or skin cells
- Fingerprints: left on surfaces
- Footprints: made in dust, mud, or other soft surfaces

The importance of Locard's exchange principle

By understanding and applying Locard's exchange principle, investigators can:

- Link suspects to crime scenes
- Identify the sequence of events
- Corroborate witness testimony
- **Exonerate** innocent individuals

Exonerate – free someone from blam...

It allows forensic scientists to piece together the puzzle of a crime by examining th...

Recall questions

1. Explain key di... ...between criminal law and civil la...
2. Ex... ...t is meant by Locard's exchange principle. ... an example of this in action.

Difference between forensic biology and forensic science

Forensic science is a broad field encompassing the application of scientific metho
crimes and examine evidence.

In essence, forensic biology is a subset of forensic science. While forensic science
scientific disciplines, forensic biology specifically concentrates on the biological as

Forensic biology is a specialised area within fo[illegible]nce that focuses on the
examination of **biological** evidence, as [illegible] **Figure 1.2**. It primarily involves:

- Pathology: The study of th[illegible]aus[illegible]and origins of diseases.
- Anthropology: The [illegible]study of human behaviour, biology, cultures, soc
  and lir[illegible]s.
- Odonto[illegible]he scientific study of teeth.
- Microbiology: The study of bacteria, fungi and viruses.
- Forensic serology: Identifying bodily fluids (blood, semen, saliva) at crime sce
- Forensic botany: Using plant evidence to link a suspect to a crime scene.
- Forensic entomology: Studying insects to obtain biological evidence from the

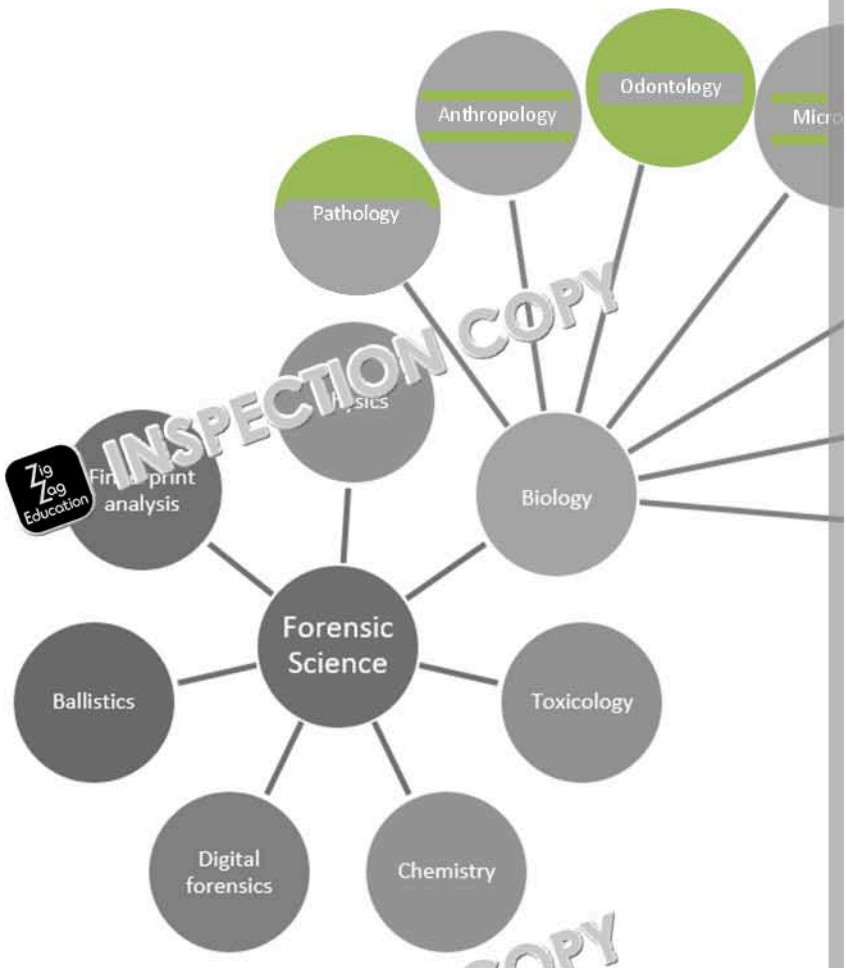

Figure 1.2 *Diagram showing the difference b[illegible]rensic science and forensic biology and th*

Disciplines associated with forensic biology (1.2.1)

As shown in **Figure 1.2**, there are a number of different disciplines within forensic

Serology

Serology focuses on the identification and characterisation of biological substances s

The key roles of a forensic serologist are:

- Detection: Identifying potential biological stains at a crime scene.
- Identification: Determining the type of bodily fluid present (blood, semen, sa
- Classification: Categorising the biological material (e.g. blood type, species or
- Preparing samples for DNA analysis.
- Bloodstain pattern analysis: Bloodstain patterns can provide clues about the occurred at a crime scene.

Pathology

Pathology studies the causes and origins of diseases. Pathologists play a vital role examining tissues, organs, bodily fluids, and even the whole body in some cases.

Forensic pathology is a specialised branch of forensic biology that applies medical investigations. Forensic pathologists investigate deaths that are sudden, unexpect find the exact cause and time of death.

Role of a forensic pathologist

- **Autopsy**: An examination of the deceased to determine the **cause** and **manner of death**. This includes:
- External examination: Identifying injuries caused by blunt force, sharp force, gunshot, and other types of trauma (see **Figure 1.3**).
  - Internal examination: Examining organs and tissues for evidence of disease, injury or poisoning.
  - Toxicology: Testing and identifying poisons or drugs in body fluids or tissues that contributed to death (see case study 'Serial killing by poisoning' in the box below).
- **Asphyxia**: Investigating deaths caused by lack of oxygen, such as strangulation or drowning.
- **Post-mortem interval (PMI)**: Using various factors such as body temperature, **rigor mortis**, and decomposition to estimate the time since death (see **Figure 1.4**).
- Child and elder abuse: Investigating cases of suspected abuse.
- Identification: Assisting in the identification of victims through dental records, fingerprints, or DNA analysis.

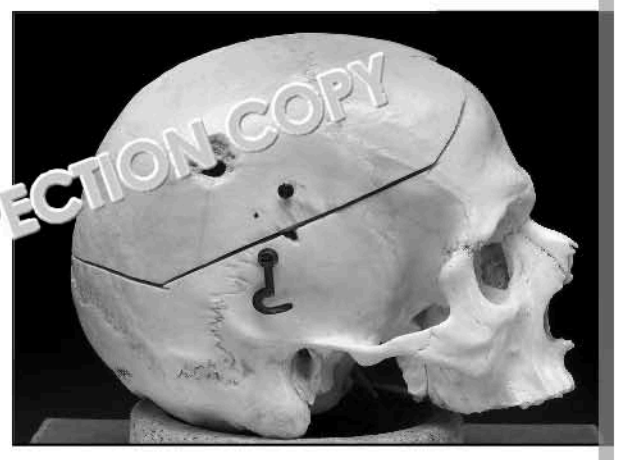

***Figure 1.3** A skull showing a gunshot trauma.*

Case study: Serial killing by poisoning

Using forensic toxicology, a nurse was found guilty of a series of poisonings five patients. By analysing post-mortem liver samples, experts detected dru to the patients, including digoxin, which is a drug used to slow heart rate.

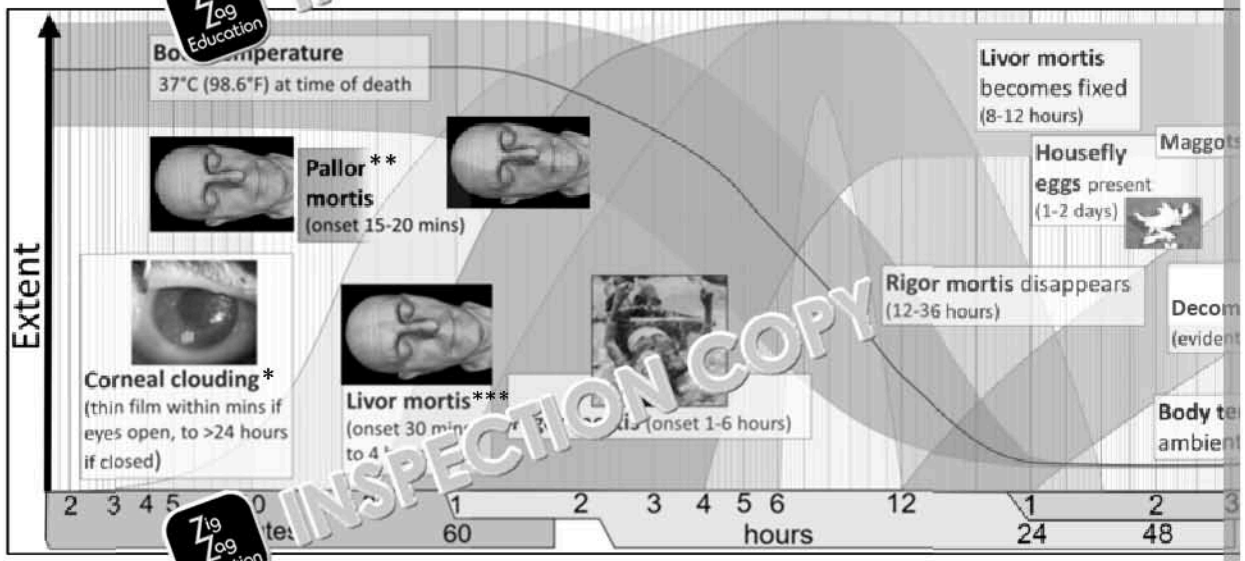

Figure 1.4 *The graph shows the approximate stages of death, also known as pos*
** Corneal clouding – when the clear, outer layer of the eye (cornea) bec*
*** Pallor mortis – when the skin of the body turns pale due to blood circ*
**** Livor mortis – when the body turns bluish-purple because of the blood settling*

Anthropology

Anthropology is the scientific study of humanity, concerned with human behaviou
societies, and linguistics, in both the present and the past. Forensic anthropology
anthropological knowledge to legal matters and involves the examination of huma

Role of a forensic anthropologist

- Recovery of remains: Assisting in the **excavation** and recovery of skeletal rem
from crime scenes or disaster sites.
- Skeletal analysis: Examining bones to determine age, sex, stature, ancestry, a
unique features of the individual to help identify victims (see **Figure 1.5** in t
'Further your knowledge' box, below).
- Trauma analysis: Identifying fractures, bullet holes, and other injuries on bon
determine cause and manner of death.
- Taphonomy: Studying the processes affecting the remains after death, such a
decomposition and scattering to estimate the time since death.
- Archaeological techniques: Using methods from **archaeology** to recover and
analyse skeletal remains.

Further your knowledge

A forensic anthropologist can estimate the age of a skeleton using the size of the skull and the squiggly lines seen in **Figure 1.5**, known as sutures. The sagittal suture, which is the wavy line that runs the length of the skull, is usually fused in people older than 35 years, and the coronal suture, the horizontal line at the front of the skull, usually fuses by the age of 40.

Figure 1.5 A skull showing the sagittal sutures which can be used to estimate age.

Case study: Reading bones to identify the dead

In the 19[illegible] young people and children were murdered by American serial k
and buried in his basement. The well-known forensic anthropologist Dr Clyde S
many of the victims using information from missing person reports.

The unknown remains of one victim found at the property was identified as 19-
went missing in 1977. According to the missing person report and historical rec
had fractured his left arm when he was a child.

When analysing one of the remains, a healed fractured left arm was evident. Th
that suggested the victim was left-handed, such as the left arm being several m
having a bevelled left scapula, led to David Talsma's identification.

Dr Snow also determined that all the victims were killed by suffocation or stran

Apply your knowledge

The Balkans Conflict:

Between 1992 and 1995 the Balkan War resulted in 35,000 missing people. During the
200 men were killed on the top of a cliff on Mount Vlašić, a mountain in Bosnia. They fell
were left in a mine around 400 m deep. The site where their bodies lie is at an altitude
Forensic anthropologists are still working to identify the missing people.

- Research and explain what role a forensic anthropologist might have in the case b
- Discuss the challenges they might have in identifying the missing persons.

Odontology

Odontology is the scientific study of teeth, their structure, development, and dise
specialised branch of dentistry that applies dental knowledge to the legal system.
expertise to examine, evaluate and interpret dental records.

Role of a forensic odontologist:

- Identification of human remains: By comparing dental records (such as X-rays
teeth of unidentified remains, they can help to establish the identity of victim
disasters, fires, or when bodies are severely decomposed. See **Figure 1.6** of a post-mo
unidentified male found in 1996.
- Bite mark analysis: Forensic odontologists can analyse bite marks found on victims or objects to link a suspect to a crime. This involves comparing the bite mark to dental impressions of a suspect.
- Age estimation: By examining dental development and wear patterns, a forensic odontologist can estimate the age of an individual, which can be crucial in cases involving child abuse or missing persons.
- Child abuse detection: Dental evidence can reveal signs of abuse, such as bite marks, fractures, or malocclusion (bad bite).

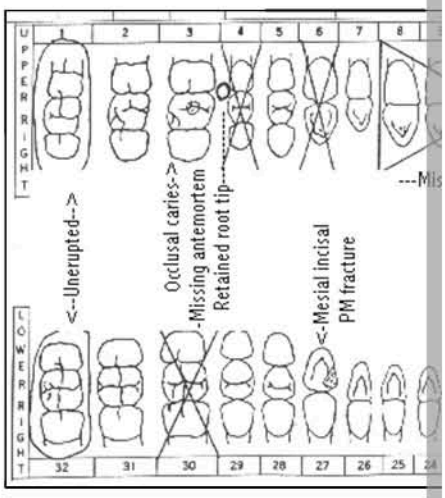

***Figure 1.6** Dental chart of an unidentifi
C , California. * O amalga*

Botany

Botany is the study of plants. Forensic botany is the application of plant science to
By examining plant material found at a crime scene, forensic botanists can provi

Role of a forensic botanist:

- Linking a suspect to a crime scene, e.g. using plant matter to place a suspect
- Determining the post-mortem interval (PMI) using the types of plants growin
time of death.
- Reconstructing crime scenes: By analysing the distribution of plant materials,
movement of victims or suspects (see the case study 'Solving murders with p
- Identifying geographic origin: Plant materials can help determine the origin o
involved in a crime.

Case study: Solving murders with plants

***Figure 1.7** Fallen oak leaves in a woodland.*

In August 2022, Robert Kern Jr was
murder of a 1 year-old girl who wa
woodland nearly an hour away from
botanist, was called to help with the
found in an area with many species
grapevines. Dr Hardy discovered tha
were found in Kern's car. After anal
their rather unique morphologies w
at the crime scene. He also found th
suggesting that the leaves had been
Figure 1.7). This matched the two-w
crime could have been committed.
importance of botany in bringing cri

Ornithology

Ornithology is the study of birds. Forensic ornithology is another relatively new field. It involves the identification and analysis of bird remains to aid in criminal investigations, accident reconstruction, and wildlife conservation efforts.

Role of a forensic ornithologist:

Key applications of forensic ornithology

- Crime scene investigation:
  - Identifying bird species found at a crime scene can link a suspect to a specific location, even with small quantities of droppings or feathers (see **Figure 1.8**).
  - Determining the time of year based on bird behaviour or migration patterns can help establish a timeline.
  - Analysing bird remains for toxins or poisons can provide evidence of foul play.
- Wildlife crime:
  - Identifying illegally traded bird species or their parts.
  - Investigating poaching and trafficking activities.

Apply your knowledge

A 25-year-old male was reported missing and a week later was found dead in a woodlan
A feather and some intact leaves were found in the car of a suspect.

- Explain how forensic ornithologists could aid this investigation.
- Explain how forensic botanists could aid this investigation.

Entomology

Entomology is the study of insects. Forensic entomology is a field that involves us details about a crime, such as the time of death.

Role of a forensic entomologist:

- Determining time of death: Insects are attracted to decomposing bodies alm the types of insect present, their life stages, and the rate of their developme estimate the post-mortem interval (PMI).
- Locating the crime scene: Some insect species are specific to certain geograp a body are typically found in a particular area, it can help pinpoint where the
- Vehicle use and past locations: Remains of insects found on the fronts of veh the vehicle was used.
- Detecting drug overdose or poisoning: Certain insects may be attracted to sp clues about the cause of death.
- Revealing abuse or neglect: In cases of child abuse or neglect, insect evidence severity of neglect.

Contribution of microbiology to forensics (2.3.1)

Microbiology is the study of **microorganisms**: mainly bacteria, viruses, fungi and protists. By analysing bacteria, fungi and viruses, forensic microbiologists can provide crucial evidence for solving crimes and identifying the perpetrator.

Key contributions of microbiology to forensic science

- Post-mortem interval (PMI) estimation:
  - **Necrobiome** analysis: The **microbial** community on and within a decomposing body undergoes predictable changes over time. By analysing this microbial profile, forensic scientists can estimate the **PMI** since death.
  - **Insect necrobiome**: Insects that colonise a corpse carry specific microbial communities. Studying these microbes can provide additional clues about the PMI.
- Place of death:
  - Microbial **fingerprinting**: The microbial composition of different environments is unique. By comparing the microbial profile of a crime scene to that of a suspect's clothing or body, investigators can establish potential links.
- **Bioterrorism** and **biocrime** investigations:
  - Microbiological analysis helps identify the causative agent in cases of biological attacks, aiding in the investigation and prevention of further harm.
- **Biosecurity**:
  - Forensic laboratories often handle potentially hazardous biological materials, such as blood, bodily fluids and unknown substances, which carry an infection risk. Proper biosecurity measures safeguard the health and safety of laboratory staff.
  - Contaminated biological evidence can compromise the integrity of forensic investigations. Biosecurity protocols help maintain the chain of evidence and prevent tampering or degradation of samples.
- Cause and manner of death:
  - Identification of **pathogens**: Microbiological analysis can detect the presence of pathogenic bacteria or viruses that may have contributed to a victim's death.
  - Toxicology: Microorganisms can be used to degrade or produce toxins, and their presence can provide evidence of poisoning.
- Individual identification:
  - Microbial signatures: Everyone has a unique microbial profile, which can be used to identify remains or link suspects to crime scenes.
- Foodborne illness outbreaks:
  - Source tracking: Microbiological analysis of food samples can help identify the source of a foodborne illness outbreak, protecting public health (see the case study 'Killer bug').

Your turn

Create an infographic or a mind map outlining the key contributions of microbiology for display in a sixth-form college.

Case study: Killer bug

In May 2024, over 120 people were hospitalised and one person died because
Shiga toxin-producing Escherichia coli (STEC) thought to have originated from
pre-packaged supermarket sandwiches. E. coli poisoning is an illness caused by
with E. coli (a type of bacteria). Symptoms include severe diarrhoea, vomiting,

The UK Health Security Agency (UKHSA) investigated the case. Their investigati
microbiologists performing DNA analysis techniques such as the **polymerase ch
check for the presence of the bacteria's DNA, and whole genome sequencing (
analysing all of the bacterial DNA to identify and characterise the microorgani
confirmation of the outbreak strain and was critical for the protection of public

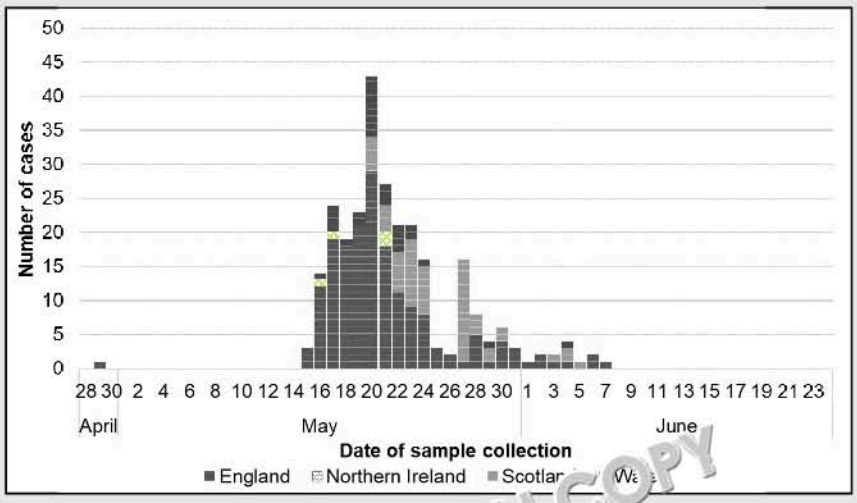

Figure 1.9 The number of confirmed cases per week.

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Formative discussion questions:

Read the scenario 'Who robbed the corner shop' on page 2.

- What evidence could be obtained from the crime scene and the suspects, and whic could help?
- Present your findings in a mind map.

Planning to preserve a crime scene and co
and explaining your choices

Key points covered

- Restriction of the scene and access to the scene
- Search patterns
- Recording and documenting the scene
- Evidence available from crime scenes and individuals, relevant to forensic biology
- Relative importance of
- Types of evidence and
  - Types of observati
  - Cellular evidence in
  - Tissue evidence in
  - Organ evidence in

Preserving a crime scene (3.1.1)

Access to a crime scene is restricted by marking an area with police tape and havi
day. Sometimes a forensic tent is erected to protect the area from weather and o
Usually, a **cordon log** is kept where details of those entering and leaving the area

Figu Forensic tent and police tape to cordon off the crime scene.

Reasons for restriction:

- Chain of evidence: Limiting access helps maintain the integrity of evidence a
  tampered with.
- Contamination prevention: Unauthorised personnel could accidentally destr
  forensic material.
- Investigation sensitivity: Protecting ongoing investigations and the privacy of

Who typically has access:

- Police officers are usually first to arrive at the scene. **Scene of crime officers (SOCOs)** collect evidence and document the crime scene. Detectives interview witnesses and discuss the evidence with the SOCOs.
- Scientists, forensic psychologists and specialists in v s forensic disciplines contribute their expertise.
- Prosecutors, defence lawyers and j ay need access to evidence for le

Recall questions

1. Suggest why it is important to restrict access to the crim

Tip!

When you do your assignment, for every step of the plan you created, you should consider the fol

1. Were any changes to the plan required? If so, why?
2. What was the reason for this part of the plan? Did it achieve its objective in protecting the e and disturbance?

Search patterns

Search patterns are systematic methods employed by forensic investigators to en
an entire crime scene. The choice of pattern depends on factors such as the size a
and the available resources.

The five most common search patterns are:

- Lane search: Investigators form a line and walk in a straight line from one end
other. This pattern is effective for large outdoor areas.
- Grid search: Similar to the lane search, but investigators retrace their steps in
direction, creating a grid pattern.
This method is highly effective for finding small pieces of evidence.
- Spiral search: Investigators move in an inwards or outwards spiral pattern fro
This method is useful for small crime scenes, and where the boundaries are u
- Wheel or ray search: Several investigators move outwards from a central poi
This pattern is suitable for open areas.
- Quadrant search: The crime scene is divided into smaller sections, and each s
team member. This method is effective for confined, large, and complex crim

Factors affecting search pattern selection:

- Size and shape of the crime scene: Large, open areas might require a strip or
enclosed spaces might be better suited for a spiral or zone search.
- Number of investigators: The available personnel will determine the feasibilit
For example, a spiral search pattern can be done by one investigator.
- Type of crime: The nature of the crime can influence the search focus. For ex
a more detailed search for trace evidence.
- Time constraints: Urgent cases may require a quicker search pattern, such as

Apply your knowledge

Create your own example search route for each of the five common search patterns, and jus
suitable for the area to be searched in each pattern chosen.

Formative discussion questions:

Read the scenario 'Who robbed the corner shop' on page 2 and discuss the following qu

- How will you preserve the appearance of the crime scene?
- How will you restrict access to the crime scene and relevant site locations?
Explain your reason for restricting access.

Class and individual evidence

There are various types of evidence that can be collected from crime scenes and individuals. These types of evidence can be categorised into **class evidence** and **individual evidence**.

Class evide
narrow dow
placing them
used to iden

Individual e
down the list
be used to id

For example, if a shoe print was left at a crime sc ne. fo ensic scientists will examine the impression a a ple of the suspect's trainer (as seen in **Fi e 1. 1**

If the impr wa nd to match the model and size of the shoe, the sh t would be described as class evidence. Some class characteristics seen in **Figure 1.11** include:

- Arch section split up into nine sections.
- Heel section split into four quarters.
- Nike logo in the same position as the shoe print impression.
- '5.0' marking in the same position as the shoe print impression.
- 'Nike Free' written in the same position as the shoe print impression.

Forensic examiners will also look for individual evidence. As seen in **Figure 1.11**, the impression (on the left) shows 12 characteristics (circled in the photo) that are distinct to that particular shoe (on the right). The individual characteristics are caused by normal wear and tear.

Figure
impr

Biological evidence

Biological evidence includes h skin ones and teeth, and bodily fluid. It can pr information about th perpetrator. Microorganisms are also a form of bi

Physical e idence

Physical evidence is any tangible object that can connect an offender to a crime s things that could constitute physical evidence, but we can group them into catego

- Impression evidence, such as footprints, fingerprints, bite marks, etc.
- Firearms and ammunition
- Evidence collected from individuals, such as clothing, documents, personal b

Note that some types of physical evidence are also biological, and physical eviden with any biological evidence that is available.

Recall questions

1. What is the difference between s evidence and indiv Give an example for ea

Trace evidence

Trace mear y s ll quantity. Trace evidence refers to tiny pieces of materia between pe bjects or environments. Examples of trace materials are fibres, from paint or glass.

Relative importance of each type of evidence

The relative importance of biological, physical and trace evidence in forensic scien
depending on the specific case, as shown in **Figure 1.12**, below.

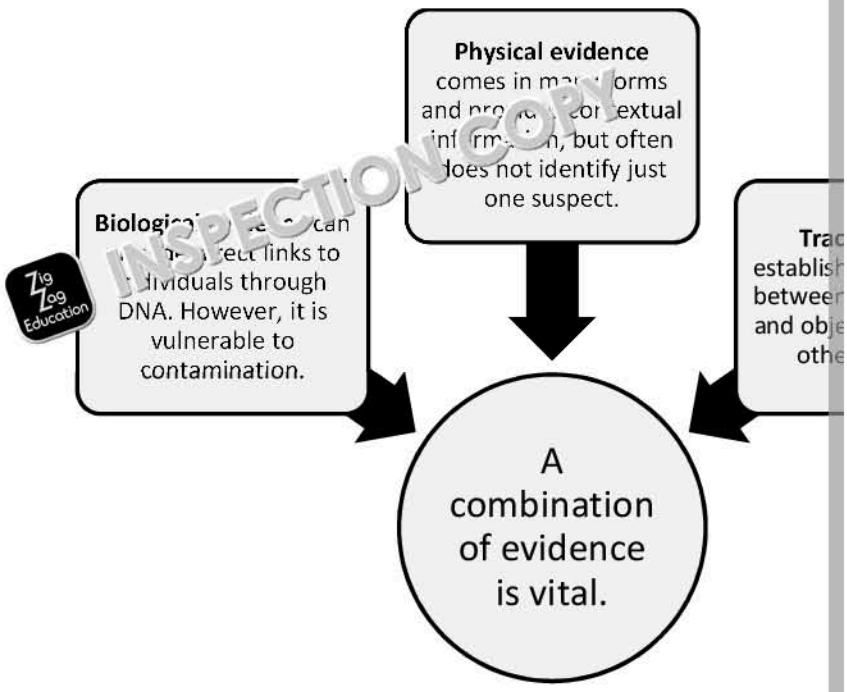


***Figure 1.12** Shows the relative importance of different types of evi*

For instance:

- Trace evidence (fibres from a suspect's clothing might link a suspect to a cri
- Physical evidence (a tool mark on a door at entry point) might place a suspect
- Biological evidence (DNA from blood at the scene) might definitively identify

No single type of evidence is more important than another. The value of evidence
reliable information and support a logical conclusion.

Apply your knowledge

a) Suggest what sorts of evidence have high **probative** value. Justify your answer.
b) Biological evidence can be used to identify a person. Apart from identification, suggest two other purposes of biological evidence and why revealing that information is important.

Types of evidence

Often, the initial visual observation of evidence can yield much information even
laboratory analysis has been done. It is important to note what kinds of evidence
complete an effective search.

Cellular evidence in forensic biology (2.2.1)

Cellular evidence can come from a variety of sources, from bacteria and yeasts th

Bacteria

Bacteria are increasingly being used as evidence in forensic science. This is due to unique microbiome, which is the collection of bacteria that live on and in their bo found on a variety of surfaces, including skin, hair and clothing. By analysing the b scientists can potentially identify the person who was in contact with that surface

There are a number of differ ways that bacteria can be used as evidence in for

- Identifying the so a biological sample: Bacteria can be used to identify sampl as blood, semen or saliva. This can be helpful in cases of rape, m
- Determ the time of death: Bacteria can be used to determine the time o and types of bacteria that are present on a body change over time as the bo
- Linking a suspect to a crime scene: Bacteria can be used to link a suspect to a suspect's hands, clothing, or other objects can be transferred to the crime sc
- Identifying the origin of a biological weapon: Bacteria can be used to identify weapon as bacteria in a biological weapon will often have a unique genetic si

There are a number of challenges associated with using bacteria as evidence in fo

- The microbiome is not static: The populations of microorganisms in the body make it difficult to link a suspect to a crime scene based on the bacteria that
- Bacterial samples can be easily contaminated: The introduction of new bacte difficult to determine the true source of the bacteria.
- There is a lack of standardised methods for analysing bacteria which makes it from different laboratories and makes it challenging to get admissible eviden

Yeast and unicellular algae

Yeast is a unicellular fungus, and unicellular algae are photosynthetic microorgani While not as extensively studied as other biological evidence, such as D unicellular algae do possess potential.

Potential a ions

1. Post-m interval estimation:
   - Certain yeast and algae species thrive in specific environmental conditio humidity and light exposure. By analysing their growth patterns on a dec scientists might be able to estimate the post-mortem interval (PMI) with
   - The presence or absence of specific species could indicate the environm decomposed, aiding in crime scene reconstruction.
2. Crime scene reconstruction:
   - These microorganisms can be used as indicators of environmental condit example, the presence of specific algae species might suggest the presen
   - Analysing the distribution of yeast or algae on a body or objects can pro of the body or objects within a crime scene.
3. Geographic profiling:
   - Some yeast and algae species are specific to certain geographic regions. on a piece of evidence, investigators might be able to narrow down the
4. Trace evidence analysis:
   - Yeast and algae can be found on various surfaces and can be transferred This could potentially be used to link suspects to crime scenes or victims

Challenges and future research

- Limited database: A comprehensive database of yeast and algae species and various conditions is still under development.
- Contamination risk: Contamination with environmental microorganisms duri analysis can be a significant challenge.
- Complexity of analysis: Identifying and analysing yeast and algae species can complex process.

Pollen and fungal spores

Pollen, mostly from wind-pollinated plants, and fungal spores are everywhere. Th
and even the soles of shoes.

Using pollen and fungal spores in forensic biology is known as forensic palynology
pollen and spores to link individuals, objects, and crime scenes.

How pollen and spores become evidence

- Unique signatures: Each geograph[illegible]n, even small areas, has a distinct
  This allows investigators t[illegible] the origin of a sample.
- Persistence: Pollen [illegible] spores are incredibly resistant to decay, making them
- Ubiqui[illegible] me[illegible]ioned above, these microscopic particles are everywhere.
- Variety [illegible]nd simply identifying location, pollen can indicate the time of ye
  the type of pollen present.

Applications in forensic science

- Linking suspects to a crime scene: If a suspect's clothing contains pollen or sp
  it can strongly suggest their presence.
- Establishing timelines: By analysing the types of pollen present, investigators
  crime occurred.
- Identifying body dump sites: Pollen and spore profiles from a body can help d
  before being moved.
- Verifying alibi: If a suspect claims to have been elsewhere, pollen evidence ca
  their story.
- Drug and botanical analysis: Pollen and spores can be used to identify the ori
  illegal substances.

While forensic palynology is a powerful tool, it does face challenges:

- Database development: Comprehensive pollen and spore databases are esse
- Expert analysis: Skilled [illegible]ologists are required to interpret the complex pa
- Sample co[illegible]tan[illegible]on: Careful handling is crucial to prevent contamination,
  compr[illegible]evidence.

Evidence from human cells

In forensic science, biological evidence can be collected from a crime scene to ide
the crime. Skin cells, cheek cells, and blood cells are all valuable sources of DNA e
these purposes.

- Skin cells: Can be transferred during physical contact, leaving them on clothin
  a crime scene. DNA extracted from the cells can be used to identify the indivi
- Cheek cells: Cells from the inside of the cheek detach continually and are fou
  located – on cigarette butts, discarded food, cups, drinking glasses and utens
  been sealed with saliva. DNA can be used for identification.
- Blood cells: Blood cells can provide a wealth of evidence in forensic science, f

Limitations of human cells:

- DNA can be easily damaged by fac[illegible]rs [illegible]as light, heat, bacteria and mould
- Contamination: DNA sam[illegible] can be easily contaminated with other people's
  have not had dir[illegible]ct [illegible]act with the object.

2.2.2 Tissue evidence in forensic biology

A tissue is defined as a group of similar cells that work together to perform a spec
can provide evidence include hair, skin, blood and bodily fluids.

Hair

Hair is a rich source of information for forensic investigati While DNA analysis
microscopic examination can reveal a wealth of de is.

Macroscopic examination

- Colour: Can provide cl ut the ethnicity, age, and potentially hair treatr
  reliable than DN is.
- Length xt e: Can provide clues about the individual's origin or occupa
- Damag ence of hair treatments, environmental factors, or trauma.

Microscopic examination

- Scale pattern: Determines species origin (human or animal).
- Medulla: The central core of the hair can vary in thickness and pattern, aidin
  sometimes providing racial indicators.
- Cortex: The main body of the hair, containing pigment granules, can reveal c
  other treatments (see **Figure 1.13**).
- Root: The presence of a root can enable DNA analysis, but even without a ro
  can be compared to known samples.
- Origin of the hair: Identifying the body part (head, pubic, etc.) from which th

Other evidence from hair

- DNA analysis: Especially where the hair root contains a follicular tag (tissue s
  DNA can be extracted for individual identification.
- Additionally, by studying the core of the hair str edulla) and the pigme
  can determine if a sample matches hair fo idence.
- Toxicology: Detecting drugs, po or heavy metals that the individual has

Figure 1.13 An electron micrograph of human hair.

Limitations evidence

- Identification: While microscopic examination can provide strong evidence, i
  definitively link a hair to a specific individual without DNA analysis.
- Contamination: Hair evidence can be easily contaminated, which can affect t
- Time frame: The amount of DNA available in a hair sample decreases over ti
  obtain a profile.

Skin

Skin can provide crucial evidence in forensic investigations. It can reveal details ab
perpetrator, and the circumstances of a crime.

Types of evidence from skin include:

- DNA analysis
- Wound analysis:
  - Weapon identification: The shape, si e and pth of wounds can indicat
  - Assault pattern: Multiple w ds reveal the sequence of events and
  - Defensive wounds: I ies sustained while trying to protect oneself can
    victim's ac
- Trace e:
  - Fib lothing fibres can transfer to the skin and be recovered.
  - Drugs or poisons: Substances absorbed through the skin can be detecte
  - Gunshot residue (GSR): Particles from a firearm can embed in the skin.
- Skin conditions:
  - Diseases: Certain skin conditions can help identify a victim or provide clu
  - Injuries: Burns, cuts and bruises can indicate the nature of a crime.

Challenges and limitations

- Skin degradation: Skin can decompose rapidly, making evidence collection di
- Contamination: Skin can be easily contaminated, affecting DNA analysis.
- Individual variation: Skin conditions and healing processes vary among indivi

Blood

Blood is one of the most common and informative t es evidence found at crin

Types of evidence from blood include:

- Bloodstain pattern analysis (B
- DNA analysis
- Blood t na
- Toxico tecting drugs, alcohol or poisons in the blood
- Disease analysis

Blood evidence can:

- Place a suspect at a
- Establish the seque
- Identify the victim
- Determine the caus
- Provide evidence of

Bodily fluids

Bodily fluids can be valuable sources of evidence. Biologically, not all of these are
- Semen: Contains spermatozoa and other cells, used for DNA profiling and pa
- Saliva: Saliva contains DNA and is found in spit, on cigarette butts, on bite ma
- Urine: Can reveal the presence of drugs, alcohol or poisons, or some illnesses
- Sweat: Can be used to test for drug use.

2.2.3 Organ evidence in forensic biology

Evidence can be obtained from both animal and plant organs.

Teeth

Teeth are incredibly resilient structures, making them invaluable in forensic invest
Here's how they can be used:

- Identification
  - Dental records: Comparing dental [illegible] (including fillings, crowns, ext characteristics) to the re[illegible]eth can positively identify a victim.
  - Bite marks: Impr[illegible] on skin or objects can be compared to a sus How[illegible], [illegible]od is often debated for its reliability.
- Age es[illegible]n
  - To[illegible]evelopment: By examining the stage of tooth development (erup odontologists can estimate a person's age, especially in children and ad
  - Wear and tear: Signs of wear, such as attrition and plaque build-up, can
- Trauma analysis
  - Bite marks: As mentioned, bite marks can help identify a suspect but ca the nature of an attack.
  - Tooth fractures: Examining broken teeth can reveal details about the fo assault or accident.
- Other evidence
  - DNA: Teeth can contain DNA, especially in the pulp, which can be used f
  - Drug analysis: Teeth can absorb and retain drugs, providing a history of

Limitations: While teeth offer valuable information, it's important to note that fac changes, decomposition, and the quality of dental records can affect the accuracy can change over time, making teeth evidence less reli[illegible]. Additionally, dental re

Bone and skeletal anatomy

Bones and teeth are incred[illegible]t biological materials, often the only remains l disaster. By an[illegible]in[illegible] remains, experts can determine various aspects of an i

- By exa[illegible]bone growth patterns, fusion of bones, and changes in bone m anthrop[illegible]gists can estimate the age at death.
- Pelvic bones, skull, and long bone features are crucial in determining biologic
- Long bone measurements, particularly femur and tibia, can approximate the
- Skeletal features, such as skull shape and measurements, can provide clues a
- Examination of joint surfaces can reveal information about age, activity level
- Comparing unique features such as healed fractures, dental work, or bone di aid in positive identification.
- Trauma analysis:
  - Cause of death: Examining fractures, bullet holes, tool marks, and other injuries can determine how the person died.
  - **Perimortem** injuries: Distinguishing between injuries sustained around t time of death and those occurring after death helps reconstruct the crim
  - Weapon analysis: The shape and characteristics of bone fractures can sc indicate the type of weapon used.
- Post-mortem interval (PMI):
  - Bone decomposition: Ob[illegible]anges in bone colour, texture, and ins time since death.
- Additional[illegible]fo[illegible]:
  - Li[illegible]and health: Analysing bone abnormalities and isotopic signatur the[illegible]vidual's diet, occupation, and overall health.
  - DNA analysis: Extracting DNA from bone can help identify individuals an

Although bone evidence provides an abundance of information, it can be difficult ancestral origin using bone fragments. Challenges are also presented when deter post-mortem injuries when bones are fresh. It is also very difficult to obtain DNA f

Leaves

Leaves, often overlooked in crime scene investigations, can provide valuable fore
as forensic botany.

How leaves can be used as evidence:

- Linking a suspect or an object to a crime scene:
  - Leaf morphology: The shape, size and venati[illegible] pattern) of leaves c
    species, narrowing down the possibl[illegible] location.
- Determining time of death or bu[illegible]
  - Decomposition rate[illegible] condition of leaves found on or near a body ca
    post-morte[illegible]
  - S[illegible] indicators: The types of leaves present can indicate the time of
    bo[illegible] buried.
- Identifying primary and secondary crime scenes:
  - Leaf transfer: By analysing the types of leaves found on a suspect, victim
    determine where they/it may have been.
- Reconstructing crime scenes:
  - Leaf position and damage: The position and condition of leaves at a crim
    the events that took place.

Forensic botany: seeds and fruits

Study of seeds and fruits in criminal cases is also part of forensic botany. Seeds an
clues in forensic investigations, such as:

- Time of death: Certain plant species have specific fruiting or seeding seasons
  the time frame of a crime.
- Geographic origin: The presence of specific plant [illegible]es can indicate the loc
  where a body was moved.
- Link to a suspect: If a suspect's cl[illegible]belongings contain(s) plant materi
  scene, it can establish a li[illegible]between the two.
- Dietary habits: A[illegible]s of seeds and fruits found in stomach contents can re
  recent[illegible] habits.
- Identify[illegible] location of a hidden body: By analysing the types of pollen an
  forensic botanists can determine the environment where the body was conc

Forensic botany: flowers and roots

Forensic botany also covers the study of flowers and roots in criminal cases.

Flowers:

- Pollen analysis (palynology):
  - Pollen grains are unique to specific plant species and can be found on cl
  - By analysing pollen, investigators can determine the location, season, and e
  - Pollen can link a suspect to a crime scene or exclude them as a possibilit
- Flower identification:
  - Certain flowers are associated with specific [illegible]s or climates.
  - Identifying flowers found at a crime [illegible]e can help establish the origin c

Roots:

- Soil analysis:
  - R[illegible]n provide information about the soil composition at a crime sce
  - So[illegible]ples can reveal the presence of specific minerals, pollutants, or
  - Root systems can also indicate disturbances, such as a recent grave.
- Plant growth patterns:
  - The growth patterns of roots can help determine the age of a crime scene
  - By examining root growth, investigators can estimate how long a body h
    plant has been growing in a particular location.

Examples of forensic botany in action:

Forensic botanists use a variety of techniques to analyse plant materials, including

- Microscopy: Examining the structure of plant cells and tissues under a microscop
- DNA analysis: Comparing the DNA of plant material found at a crime scene to provide a positive identification.
- Pollen analysis: Studying pollen grains can reveal the types of plants present used to track the movement of people or objects.
- Seed and fruit identification: Comparing the physical characteristics of seeds collections can help identify plant sp

To extract maximum information from evidence, forensic scientists employ variou

- Microsc Ex leaf structures and identifying unique characteristics.
- DNA a Comparing leaf DNA to reference samples to determine plant s
- Pollen a spore analysis: Identifying specific pollen and spore types to link t
- Stable isotope analysis: Determining the geographic origin of a plant based o

Forensic botany can be a challenging field due to the following factors:

- Plant material can degrade over time, making it difficult to analyse.
- There may not be complete reference collections of all plant species in a give
- The interpretation of plant evidence can be subjective and may require expe

Observational evidence (4.1.1)

Fingerprints and footprints

Fingerprints – the unique patterns formed by the ridges and valleys on our fingertips – have been a cornerstone of forensic science for over a century (see **Figure 1.14**). Their distinctive nature and permanence make th luable tools for id g individuals and linking them me scenes.

A

B

Figure 1.14 *A) Anna Timiryova, and B) her fingerprints taken in 1954. Anna Timiryo who was arrested for allegedly spreading anti-Soviet propaganda*

When a forensic expert arrives at a crime scene, their initial focus is on identifying
These might include:

- Obvious surfaces: Windows, doors, furniture and appliances.
- Latent prints: Invisible prints that require development techniques.
- Patent prints: Visible prints left by substances such as blood, ink and grease.
- Plastic prints: Impressions made in soft materials such as wax or putty.

The type of print found will influence the subsequent analysis and development te

Recall questions

1. Suggest how footprints can be used to provide class an
2. Suggest how a fingerprint might be preserved. Explain

Other types of prints

Ear print analysis is a relatively new field in forensics, but it is showing promising potential as an identification tool (see **Figure 1.15**). Here are some initial observations:

- Uniqueness: Like fingerprints, ear prints are believed to be unique to each individual. This makes them a potential powerful tool for identification.
- Persistence: Ear prints can be left on various surfaces, including glass, metal and fabric, making them potentially valuable evidence at crime scenes.
- Complementary to other evidence: Ear prints can corroborate other forms of evidence, such as DNA or fingerprints, strengthening the case against a suspect.

Lip prints offer a unique potential in forensic investigations.
While not as widely utilised as fingerprints or DNA, they can provide valuable supplementary information.

Beyond identification, lip prints can potentially provide information about:

- Number of individuals: Multiple lip prints may indicate the presence of more than one person.
- Sex: Some studies suggest potential sex determination based on lip print characteristics.
- Habits: Certain lip habits (e.g. biting, smoking) may leave distinctive marks.
- Force applied: The pressure used to create the print can provide clues about

Fingernails and associated skin cells

Fingernail clippings and chips from nails can be a gold mine of forensic evidence. T
substances or materials that can link a suspect to a crime scene or victim, includin
detected using microscopy.

Trace evidence

- Fibres, paint chips and soil particles can place a person at a particular crime s
- Drugs or explosives: Residues of these substances can be detected in nail clip
of exposure.

DNA evidence

- Associated cells: As mentioned, skin cells under the nails can be a rich so
- Blood: If the victim has scratched an attacker, blood may be present under th

Flies (Diptera) and beetles (Coleoptera)

Initial evidence from flies includes:

- Bluebottles (order Diptera) and houseflies: These are the first insects to arrive at a decomposing body, attracted by the odour of decaying flesh. Their arrival time can provide a crucial estimate of the initial post-mortem period.
- Maggot development: Maggots are part of the life cycle of houseflies and bluebottles. The stages of maggot development (egg, larva, pupa) follow a predictable timeline under specific environmental conditions.
  By examining the size and stage of maggots, forensic entomologists can estimate the time of colonisation and, consequently, the PMI.
- Succession of flies: Different species of flies arrive at a decomposing body in a specific order. This succession pattern can help refine the PMI estimate.

Initial evidence from beetles includes:

- Carrion beetles: These beetles (see **Figure 1.17**) arrive later in the decomposition process, feeding on dried tissues and remains. Their presence can indicate a later stage of decomposition.
- Predator and scavenger beetles: Some beetle species prey on maggots or other insects associated with decomposition. Their presence can provide additional information about the insect community and the time since death.

Figur

Other factors affecting insect evidence:

- Environmental conditions: Temperature, humidity, and geographic location significantly influence insect development rates.
- Body conditions: Factors like body size, clothing, and cause of death can affe
- Preservation of insect evidence: Proper collection and preservation of insect accurate analysis.

Fibres

Fibres are tiny strands of fabric material and can be incredibly valuable pieces of evidence in forensic investigations.

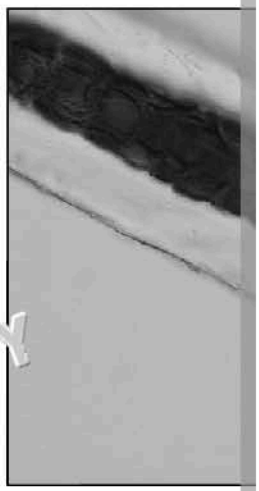


***Figure 1.18** A micro*

Initial examination and potential findings:

- Type of fibre: Natural (cotton, wool, silk) or synthetic (nylon, polyester, acrylic).
- Colour: Can be compared to fibres found on suspects or victims.
- Length and diameter: Can provide clues about the type of fabric and its use.
- Damage: Burns, tears, or other damage can provide information about the circumstances of the crime.
- Location: Where the fibre is found can be crucial. For example, a fibre found on a victim's clothing might link them to a suspect or crime scene.

While initial examination can provide valuable clues, microscopic examination is required for detailed analysis of fibre structure, including scale patterns, cross-sectional shape, and colour distribution (see **Figure 1.18** of a micrograph of a strand of wool).

You will ne
3.2.3 in or
storage of
to plan yo

Key points covered

- Hazards of forensic work at the crime scene
- Hazards of forensic

Hazards associated with forensic work (3.2.1)

Hazards at the crime scene

Collecting evidence at the scene is a crucial but inherently risky task. There are working in that are not familiar. Investigators face a variety of potential haz

Biological hazards

- Infectious diseases: Exposure to blood-borne pathogens such as HIV, Hepat
- Decomposition: Contact with decomposing bodies can lead to exposure to

Chemical hazards

- Toxic substances: Exposure to poisons, drugs, or other hazardous chemicals
- Explosive substances: Risk of exposure to unexploded bombs or live firearm
- Flammable materials: Risk of fire or explosion from substances such as gasc
- Corrosive substances: Damage to skin and eyes from acids or bases.

Physical hazards

- Sharp objects: Injuries from broken glass, needles, or weapons.
- Structural instability: Risk of collapse in damaged buildings or structures.
- Confined spaces: Difficulty breathing, lack of oxygen and other health risks

To mitigate these risks, crime scene investigators must adhere to strict safety pr

- Personal protective equipment (PPE): Use of gloves, masks, gowns, and eye p
- Proper training: Knowledge of hazardous materials, decontamination proced
- Scene security: Controlling access to the crime scene to prevent contaminati
- Documentation: Detailed records of evidence collection and handling.

Hazards in the laboratory

Key biosecurity measures in forensic laboratories

- Risk assessment: Identifying potential hazards and vulnerabilities is the first step in establishing effective biosecurity protocols.
- Access control: Limiting access to laboratory facilities and restricted areas helps prevent unauthorised entry and potential contamination.
- Biological containment: Ensuring that no microorganisms can escape from the facility through procedures and equipment put in place.
- Personal protective equipment (PPE): Proper use of PPE, such as lab coats, gloves, and face masks, protects personnel from exposure to hazardous material (see **Figure 1.19**).
- Safe handling and disposal of biological materials: Following strict procedures for disposing of biological samples minimises the risk of contamination and accid
- Emergency preparedness: Developing and practising emergency response pla crucial for mitigating potential consequences.
- Training and education: Regular training for laboratory personnel on biosecu safety culture.
- Security systems: Surveillance systems, alarms, and other security measures and detect suspicious activities.

Figure 1.19 A

Preparing a risk assessment for the crime scene and laboratory

A comprehensive risk assessment is crucial for ensuring the safety of personnel, p evidence, and the overall efficiency of operations at a crime scene and in a forens assessment should be prepared:

1. Identify potential hazards
   - The previous section lists most of these.

2. Assess the risks
   - Likelihood: How li[illegible]s it that a hazard will cause harm?
   - Sev[illegible]ity: [illegible]he potential severity of the harm?

3. Develop control measures: What can be done to reduce the risk?
   - Personal protective equipment (PPE): Gloves, masks, gowns, eye prote
   - Scene security: Controlling access to the crime scene.
   - Scene preservation: Proper handling and packaging of evidence.
   - Emergency procedures: Plans for medical emergencies or hazardous m
   - Training: Ensuring personnel are trained in safety protocols and evide

4. Implement and monitor
   - Communicate the risk assessment: Share the assessment with all pers scene investigation.
   - Review and update: Regularly review the risk assessment and make ne

5. Documentation
   - Record findings: Document th[illegible]ssessment process and the contr

Specific considerations f[illegible]nsic labs

- Chain [illegible]en[illegible]mplement strict procedures to prevent evidence contami
- Data se[illegible] Protect sensitive information from unauthorised access.
- Quality control: Establish robust quality control measures to ensure accurate
- Emergency preparedness: Develop plans for handling emergencies such as fi natural disasters.

Recall questions

1. Make a list of all the ways contamination can be avoide you have learned so far throughout the course.

Tip!

After you have completed your activity, for point D2, you will '**evaluate** the effectiveness of the so make sure that you note down anything which came up while you were doing the activity.

Formative questions:

Read the scenario on pa[illegible]wer the following questions.

A risk ass[illegible]t [illegible]ocess that identifies potential hazards, assesses the risk (whic of harm th[illegible]d may cause) and suggests some control measure (which advises how Create a risk assessment for the crime scene investigators and experts analysing the ev Include the following:

- Hazards
- Risk
- Control measures

Section 2: Investigate the crime scen collect evidence

Recording the crime scene

Key points covered

- Recor[illegible]nd [illegible]enting the scene
- Crim[illegible]notes
- Visual evidence

Recording and documenting the scene (3.1.2)

Crime scene notes

Crime scene notes are the foundational document for any forensic investigation. T of everything observed and done at the crime scene.

Importance of crime scene notes:

- Accuracy: They provide an accurate and objective record of the crime scene.
- Completeness: They capture every detail, no matter how insignificant it may
- Clarity: They are clear and concise, allowing for easy understanding.
- Timeliness: They are recorded promptly to ensure accuracy and completenes
- Legal admissibility: They can be used as evidence in co[illegible].

Crime scene notes should include:

- Basic information: Date, time, l[illegible]r, case number, and names of personne
- Weather conditions: T[illegible]re, humidity, precipitation, wind direction, a weather i[illegible]rn[illegible]
- Initial [illegible]tions: Overall description of the scene, including lighting, odou
- Evidenc[illegible]cumentation: Detailed description of each piece of evidence, incl any unique characteristics.
- Photography and sketches: References to photographs and sketches taken at
- Personnel actions: A record of who was present, when they arrived, and wha
- Chain of evidence: Documentation of the movement of evidence from the cr

Note-taking techniques:

- Clarity and organisation: Use clear and concise language, and organise notes
- Objectivity: Record only observed facts, avoiding personal opinions or interp
- Detail: Include as much detail as possible, even if it seems irrelevant at the ti
- Timeliness: Record information as soon as possible to ensure accuracy.
- Accuracy: Double-check information to ensure accuracy.

Example of crime scene notes

Date: 01/01/2024
Time: 14:30
Location: 1[illegible]igh[illegible], Anytown, UK
Case num[illegible]-0001
Personnel: Officer J, Detective S, CSI
Weather: Clear, cold, temperature 8 °C, humidity low
Initial observations: Single-storey house, front door forced open, living room in splatter on living room wall.

Evidence:

- Knife with apparent blood stains found on kitchen worktop.
- Blood sample collected from living room wall.
- Footprint on rug on living room floor.
- Fibre sample collected from sofa cushions.

Photography: Photos taken of exterior, interior, and evid e.

Sketch: Rough sketch of living room created.

Chain of evidence: Evidence collected kaged according to standard proc

Visual evidence

Visual evid crucial for preserving the crime scene in its original state and pr between ev e and the scene.

Photography and video

- Types of photos:
  - Overview photos: Establish the overall scene.
  - Mid-range photos: Focus on specific areas and evidence.
  - Close-up photos: Detail evidence with and without scales.
  - Evidence-establishing photos: Show the relationship of evidence to the s
  - Body photos: Document victim's position and injuries.
- Techniques:
  - Use different angles and perspectives.
  - Employ flash for clarity and elimination of shadows.
  - Maintain consistency in camera settings.
  - Document photo conditions (date, time, camera s t ings, lens).

Measuring

- Tools needed:
  - Measuring tapes
  - Rulers
  - La as ing devices
- Techni
  - Measure distances between key points.
  - Record measurements in a clear and organised manner.
  - Use reference points for accuracy.

Drawing

- Types of drawings:
  - Rough sketch: Created at the scene, outlines key features (see **Figure 2.1**).
  - Finished sketch: Detailed drawing with accurate measurements and labels.
  - Perspective sketch: Shows three-dimensional relationships.
- Techniques:
  - Use symbols and leg s to r esent objects.
  - Include a scal direction.
  - La ide with unique identifiers.

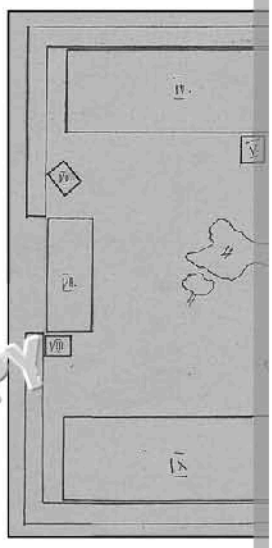


***Figure 2.1** A crime sc against František Saidl, in the Central Bohemian stabbed his own s*

Formative discussion questions:

Read the 'corner shop robbery' scenario on page 2.
Create detailed notes of the crime scene.

Key points covered

- Collection of evidence
- Storage of evidenc

Collection of evidence (3.2.2)

Evidence recognition

Recognising [illegible] crime scene is a critical first step in any investigation. It knowledge [illegible] rent types of evidence, and an understanding of how it can be

Evidence can be broadly categorised into **direct evidence** and **circumstantial evidence**.

Physical evidence is a subset of circumstantial evidence and can be further divided into:

- Biological evidence: This includes DNA, blood, saliva, hair, and bodily fluids.
- Trace evidence: This encompasses fibres, paint chips, glass fragments, soil, and gunshot residue.
- Impressions: This includes fingerprints, footprints, tyre tracks, and tool mark

Recognising evidence at a crime scene involves:

- Observation: Carefully examine the crime scene for a[illegible]bnormalities or out
- Documentation: Photograph and document [illegible]g, including the locatio
- Collection: Carefully collect evidenc[illegible] proper techniques to preserve its
- Preservation: Store evide[illegible] in a[illegible]ropriate containers and maintain the chai

Challenges [illegible] evidence:

- Evidenc[illegible]be easily overlooked or destroyed.
- The condition of the crime scene can make evidence difficult to find.
- Evidence may be transferred or contaminated.

Remember:

Proper collection and preservation are crucial to maintain the integrity of biolog

- Wear protective gear: Gloves, masks and gowns prevent contamination of th the investigators.
- Document the scene: Photographs, sketches and notes are essential for the c
- Collect samples carefully: Use sterile swabs, vacuumed collection, or other a
- Package and store properly: Prevent degradation with appropriate containe

Methods for collection of trace evidence

Collecting trace evidence requires meticulous attention to detail, and proper techniques in the correct order depending on the type of trace evidence present. Forensic examiners should always use the method which causes the least destruct first. This prevents damage and avoids contamination. For example, here are som common methods to collect trace evidence in an appropriate order:

1. Swabbing

- Purpose: Collecting tra e e id ce from larger surfaces ar
- Process: A m s d swab is used to collect samples fro used (wo b wab technique) and both swabs are proces of DNA recovered.
- Considerations: The type of swab and the collection soluti type of evidence.

2. Forceps

- Purpose: Collecting individual pieces of trace evidence.
- Process: Fine-tipped forceps are used to carefully pick up fragments, hair, or fibres.
- Considerations: Forceps must be clean and handled with

3. Tape lifting

- Purpose: Collecting trace evidence from flat surfaces.
- Process: Adhesive tape is pressed onto the surface to lift
- Considerations: Tape lifts should be placed on a clear ace

4. Vacuuming

- Purpose: Collecting a large amount of trace evidence fro
- Process: A specialised vacuum with filter is used to colle other particles.
- Considerations: The fil r m be properly labelled and pa

5. Marks a impressio

- Collecting impressions often found in soft surfac sand; and marks such as tyre marks on roads.
- Process: Lift the evidence from a hard surface using variou cast of the evidence if there is an impression in a soft surf
- Consideration: When lifting the evidence, enough pressure m

6. Print lifting

- Purpose: Collection of fingerprints.
- Process: Fingerprints can be found by dusting surfaces wit prints (see **Figure 2.2**). Fingerprints can then be lifted usin of card (called a backing card) to preserve it.
- Considerations: The lift must be stored flat and in dry con

***Figure 2.2** A forensic examiner applying a dark powder to a fingerprint, which is the fi*

Other methods

- Brushing and shaking: Clothing or other items can be brushed and shaken ov
  fibres or debris.
- Evidence collection kits: Pre-packaged kits containing various tools and conta
  types of evidence (see **Figure 2.3**).
- Collecting soil samples: Use stainless steel tools such as a spatula or spade to
  not susceptible to corrosion and is easy to clean to r[illegible] contamination. If
  a shoe, package the object and collect the so[illegible] in the laboratory. Scra
  using a paintbrush and spatula.

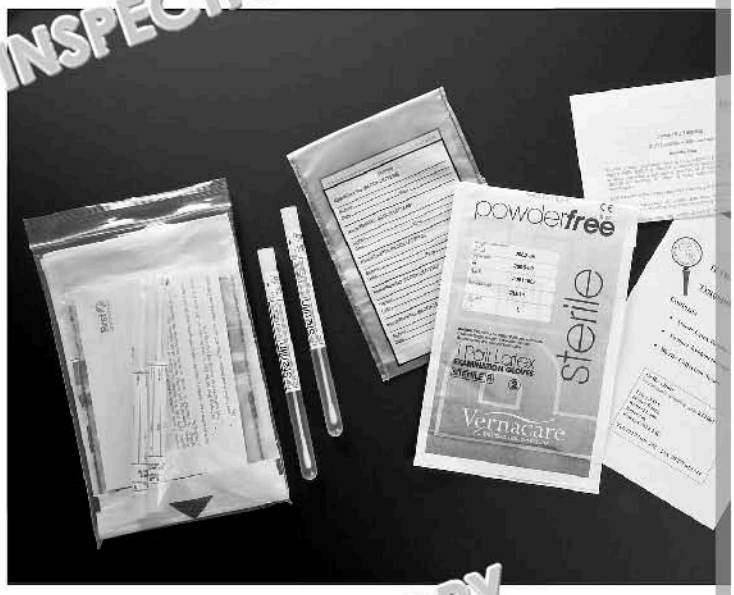


***Figure 2.3** A DNA collection kit, in[illegible] ex gloves, **sterile swabs an** labels, inst[illegible] and a tamper-evident **storage bag**.*

Important considerations

- Chain of [illegible] tain a detailed record of who handled the evidence a
- Docun[illegible]on. Photograph and document the collection process.
- Persona[illegible]tective equipment: Wear gloves, masks, and other PPE to protec

Recall questions

1. Describe how trace evidence is collected from a crime
2. Why is it important to collect trace evidence in a parti

Storing evidence (3.2.3)

Packaging

Use appropriate containers to prevent damage or loss of evidence. Generally, paper must be used to package wet evidence su[illegible]as clothing covered in bodily fluids (a wet sample degrades in [illegible]sti[illegible]ackaging). **Bindles** can be used to transport trace evid[illegible]. [illegible]tic containers or bags can be used for dry evidence (suc[illegible] soil sample or a mobile phone).

Bi
in
tra
Vi
of

Vials are used [illegible]ra[illegible] liquids. Where these are plastic, they should come with a lined lid (PT[illegible]hemical compound which is compatible with many substances)

Apply your knowledge

State one piece of evidence you might transport in: a bindle, a plastic container, a

Documentation process

1. Initial observation:
   - Note the location, type, and quantity of the trace evidence.
   - Describe any unique characteristics or patterns.
   - Take photographs and/or videos of the evidence *in situ*.
   - Sketch the crime scene showing the general layout of the crime scene in relation to the surroundings.
   - Use a scale to indicate the size of the evidence.

2. Collection:
   - th[illegible]race evidence using appropriate techniques to avoid conta
   - [illegible]e the evidence in suitable containers.
   - Seal the containers with evidence tape and create evidence labels detailing relevant information, including:
     - Case number
     - Item number
     - Date and time of collection
     - Collector's name and initials
     - Description of the evidence
     - Location of the evidence
     - Any relevant case information

At the end of the pr
effectiveness of the
Ensure you have:
- Justified your
- Made notes o
are required
- Made notes o
so you have c

3. Maintain the chain of evidence, as detailed in the next section.

4. Laboratory analysis.

Documentation challe[illegible]
- Trace [illegible]ce [illegible]n be easily lost or contaminated if not handled properly.
- Docum[illegible]n can be time-consuming and requires attention to detail.
- Interpretation of trace evidence can be subjective and open to debate.

Additional considerations
- Use standardised documentation forms to ensure consistency.
- Consider using digital photography and video to supplement written docume

Your turn

Create a training poster to remind profesionals working at crime scenes about the [illegible] to be taken in lablleing evidence.

Formative discussion question

Read the scenario 'Who robbed the corner shop' on page 2. Plan how you will collect the 'corner shop robbery' [illegible] through the recovery of trace material. Explain your ch

To answe[illegible]estion, consider the following points:
- Trace evidence is vulnerable to contamination. How would you preserve the integri the risk of contamination?
- What methods should be used to recover the evidence found at the scene of the cr chosen methods.

Proper storage of forensic evidence is crucial to maintain its integrity and admissi
The method of storage depends on the type of evidence.

Methods for storage of evidence

General storage principles are:

- Secure environment: Evidence should be stored in a lock ed, climate-controll
  contamination, and degradation.
- Chain of evidence: A detailed record of w o as handled the evidence, when
- Packaging: Evidence should be p ag appropriately to prevent damage ar
- Labelling: Clear and ac e la elling is crucial for identification and tracking
- Environm tal c ditions: Temperature, humidity, and light levels should be

Specific sto requirements

- Biological evidence:
  - Often stored frozen or refrigerated to prevent degradation.
  - Dried blood stains can be stored at room temperature in paper bags.
- Trace evidence:
  - Typically stored in paper bags or envelopes to prevent moisture build-up.
  - Some items, such as fibres, may require special storage conditions.

Furth
Wet or
be sto
provid
which
the DN

Evidence storage facilities

Many law enforcement agencies have dedicated evidence storage facilities. These
specific storage requirements and ensure the preservatio evidence. Within sc
what spaces you have available to store evidence so ha is preserved under the

Challenges in evidence storage

- Space constraints: E e storage can be costly and space-consuming.
- Eviden ra Some types of evidence degrade over time, despite pr
- Securit The risk of theft, loss or contamination is always present.
- Budget constraints: Adequate funding for evidence storage is often limited.

Movement of evidence: the chain of evidence

The movement of evidence, also called the chain of evidence, is a meticulous rec
movement, handling and possession of evidence from the crime scene to the cou
forensic investigations, ensuring the integrity and admissibility of evidence.

Importance of a chain of evidence

- Preservation of evidence: It safeguards evidence from contamination, tampe
- Legal admissibility: A complete and unbroken chain of evidence is essential fo
  in court.
- Accountability: It establishes accountability for th handling the evidence.

Elements of a chain of evidence

The elements of a chain of evidence include the following in **Figure 2.4**:

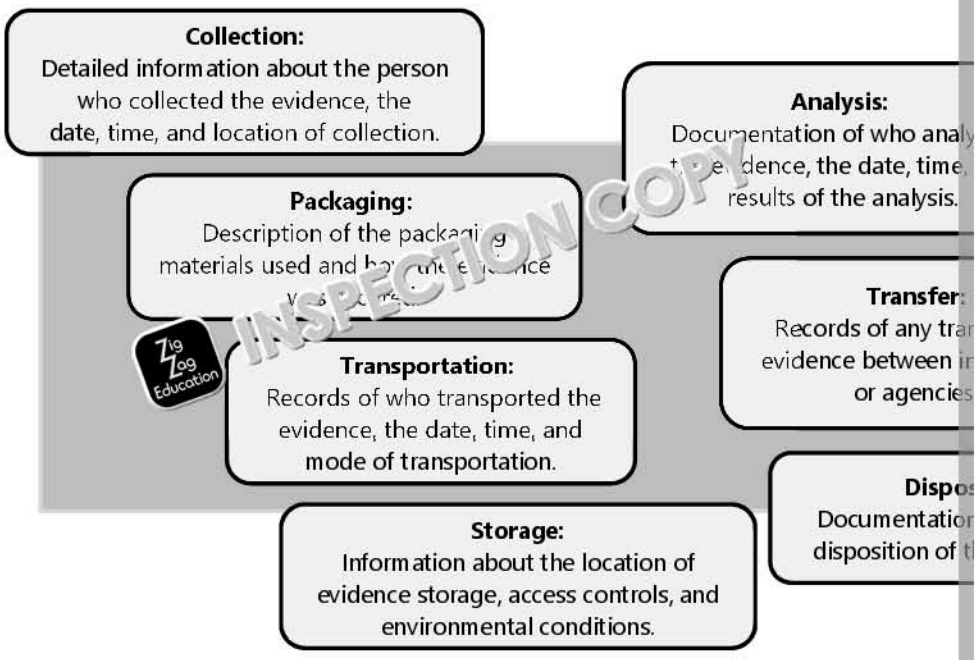


***Figure 2.4** Elements of a chain of evidence.*

A chain of evidence form is typically used to document the movement of evidence

- Unique identification number for the evidence
- Description of the evidence
- Name and signature of individuals handling the evidence
- Date and time of each transfer
- Reason for the transfer

Maintaining a chain of evidence

- Security: Evidence should be stored in a secure location with restricted acces
- Documentation: All transfers and handling of evidence must be documented
- Training: Personnel handling evidence should be trained in chain of evidence
- Review: Regular review of chain of evidence records helps identify potential i

***Figure 2.5** Security seals are added to boxes of evidence to ensure no unau*

Recall questions

1. Describe why it is important to select the appropriate p different evidence. Give an example.

Formative discussion questions:

Read the scenario 'Who robbed the corner shop' on page 2 and plan how you would pac and transport the evidence from the crime scene:

- What factors must you consider when selecting the most appropriate packaging to
- What factors would influence the appropriate selection of the storage environment f

Section 3: Analyse the evidence

Planning an analysis of the evid

Key points covered

- Preparing forensic evidence f... py
- Technology used in ... alysis
- Techniques for ana

Analysin... bservational evidence (4.1.2)

There are various techniques, some traditional and some modern, used to analyse we will discuss the most common ones.

Observation, photography, measuring and drawing

Making observations is valuable, but some record and quantification should acco admissible in court.

Photography, measuring and drawing are fundamental components of crime scen tandem to create a comprehensive and accurate record of the crime scene for an

- Photographs are used to capture visual evidence crucial for preserving the cr
- Accurate measurements provide spatial relationships between evidence and
- Drawings create a visual representation of the crime ... e to complement p

Formative discussion qu...

Read the scenario 'Wh... ...corner shop' on page 2. Consider how you would us and sketch ... analyse the evidence from the crime scene.

DNA identification

DNA profiling is a powerful tool for comparing biological evidence to suspects o 'Unmasking Colin Pitchfork' in the box below). DNA is an extremely stable molecu at crime scenes. For extraction, DNA is isolated from the biological sample; this co speck of blood.

Case study: Unmasking Colin Pitchfork

In 1983 and 1986, 22-year-old Colin Pitchfork raped and murdered two 15-year in Leicestershire.

To find the perpetrator, the police mass tested the ... of ...000 men in the are Pitchfork escaped the testing by asking a f... to ...nate a sample of their blo him bragging about getting away ... th...

In 1988, Colli... Pit... ...s arrested and it was confirmed that his DNA match This case ... ...volutionary as Pitchfork became the first person to be convicte

Polymerase chain reaction (PCR) is a powerful technique that allows forensic scie
minuscule quantities of DNA found at crime scenes. It is a method of DNA amplifi
more copies of DNA molecules that have been found. This is useful for:

- Overcoming the limitation of small samples: PCR enables the creation of milli
  sequence from a tiny starting sample. This is crucial because crime scene evi
  traces such as hair follicles, skin cells, or saliva.
- Accessing degraded DNA: PCR can effectively amplif[illegible]rease in volume) ev
  which is common in older or exposed crime [illegible]dence.

Gel electrophoresis is a laborato[illegible]e that separates DNA fragments according to si[illegible]harge by passing an electrical current through a g[illegible]nv[illegible]ese steps:

- Isolate[illegible]om sample and amplify using PCR.
- Load DN[illegible]samples to the wells at one end of the gel.
- Run an electric current through the gel.
- Stain the DNA bands and record the results.

Once amplified, the DNA can be either sequenced or profiled, or both.

DNA sequencing: Determines the exact order of **nucleotides** (adenine or A, thymine or T, cytosine or C, guanine or G) in a DNA molecule. DNA is extracted from a sample (e.g. blood, saliva, hair). It is then broken down into smaller fragments. These fragments are sequenced using advanced technologies such as Sanger sequencing or next-generation sequencing. The sequence data is assembled to reveal the complete DNA sequen[illegible]

Nucleotide – a building block of DNA.

DNA profiling: Creates a unique genet[illegible]int of an individual based on spec
This information generates a D[illegible]pr[illegible], a unique pattern representing the indiv
(see **Figure 3.2**)

Figure 3.2 *The picture above shows DNA bands on agarose gel p*

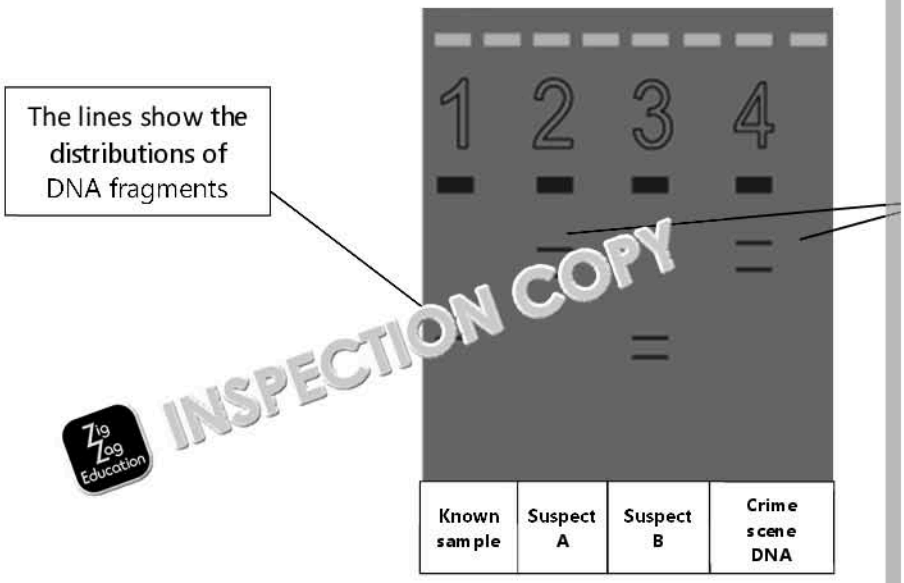


***Figure 3.3** A line drawing of the results of DNA profiling of a known sample and that of two suspec*

Forensic applications:

- Identifying suspects: DNA profiles from crime scene evidence can be compar to identify potential suspects.
- Exonerating the innocent: DNA evidence can prove the innocence of wrongly
- Paternity testing: DNA profiles can establish or exclude biological relationshi
- Mass disaster identification: DNA profiling can help identify victims of disast natural disasters.
- Wildlife forensics: DNA analysis can help track en[illegible]d species and comb

Advantages:

- High accuracy: DNA evid[illegible] is highly reliable and can provide strong eviden
- Sensitivity: DNA [illegible] can be performed on very small samples, even degr
- Indivi[illegible]city: DNA profiles are unique to each individual, except for id

X-rays and CT scans

X-rays and CT scans are indispensable tools in forensic investigations, providing cr of criminal cases.

X-rays are high-energy electromagnetic radiation that can penetrate objects and p structures. In forensics, X-rays are primarily used for:

- Examining skeletal remains: Determining age, sex, height, and identifying pre
- Investigating injuries: Revealing internal injuries, fractures, and foreign objec
- Analysing evidence: Examining objects such as weapons, tools or documents or alterations.
- Identifying victims: Comparing dental records with X-rays of unidentified rem

Computed tomography (CT) scans create [illegible] images of the body or objec different angles. In forensics, the[illegible] greater detail and precision compare

- Examining injuries: [illegible] comprehensive view of internal injuries, inclu
- Recons[illegible]ng [illegible]cenes: Visualising the position of victims and suspects,
- Analys[illegible]ence: Examining complex objects such as firearms, explosives or hidden information.
- Identifying victims: Creating detailed digital models of facial features for com

Key applications of X-rays and CT scans in forensics include:

- Homicide investigations: Determining the cause and manner of death, identi
  crime scenes.
- Assault cases: Documenting injuries, identifying weapons, and analysing the
- Traffic accidents: Assessing injuries, determining the impact point, and recon
- Archaeology and anthropology: Studying skeletal remains, analysing artefact
  ancient cultures.

Limitations and considerations:

- Radiation exposure: Both X-ray and CT scans involve exposure to ionising ra
  not used carefully.
- Cost: CT scans are generally more expensive than traditional X-rays.
- Expertise required: Interpreting X-rays and CT scans requires specialised training and k

Presumptive tests

Presumptive tests are rapid, relatively inexpensive, and easy to perform.

Presumptive tests typically involve a chemical reaction that produces a visible colour change or other observable phenomenon in the presence of the target substance. For example, a test for blood might involve a colour change, while a te for drugs might produce a specific crystal formation.

Two common presumptive tests for blood use **luminol** or leucomalachite green.

Due to its sensitivity, luminol is widely used in forensic investigations to detect trac of blood that have been cleaned or otherwise obscured. The iron present in haemoglobin, a component of blood, acts as a catalyst for the oxidation of luminol. This reaction produces a blue glow that can be seen in low-light condition

Advantages of luminol

- Sensitivity: It can detect extremely small amounts of blood, even if it has bee
- Coverage: It can be sprayed over large areas quickly, making it efficient for cr
- Visual appeal: The glowing blue light is dramatic and can be easily photograp

Limitations of luminol

- False positives: Luminol can react with other substances, such as bleach, cop producing a false positive.
- DNA degradation: The chemicals in luminol can interfere with DNA analysis, s after luminol treatment must be handled carefully.
- Light sensitivity: The glow from luminol is relatively short-lived, requiring qui

Leucomalachite green (LMG) is a common chemical reagent used in forensic scien detection of blood. It is a sensitive and relatively specific test that can be easily pe

Advantages of LMG test

- Sensitivity: It can detect even trace amounts of blood.
- Specificity: While not definitive, it is less prone to false positives compared to
- Ease of use: The test can be performed relatively quickly and easily.

Limitations

- Presumptive only: A positive LMG test does not confirm the presence of blood. **Confirmatory** tests (e.g. immunochromatographic tests or DNA analysis) are necessary.
- False positives: While less common than with some other tests, false positive occur due to the presence of certain chemicals or plant peroxidases.

Recall questions

1. Describe the difference between presumptive tests an

Blood groups

Determination of a blood group is called **blood typing**. Blood typing has been a fu
forensic science for decades.

While DNA profiling has become common in recent years, blood group analysis re
criminal investigations.

The ABO and Rhesus (Rh) systems

- ABO system: This is the most well k[illegible]lood group system. It is based on t
antigens A and B on the s[illegible]ce [illegible]ed blood cells. There are four blood types
- Rh system: This sy[illegible]s [illegible]sed on the presence or absence of the Rh factor,
cells. F[illegible]ar[illegible]ther Rh positive (Rh+) or Rh negative (Rh-).

Forensic applications

- Exclusion of suspects: If the blood type found at a crime scene does not matc
suspect can be excluded as the source of the blood.
- Inclusion of suspects: While not as definitive as DNA, matching blood types c
a suspect is the source of the blood.
- Population genetics: Blood group frequencies vary among different populatio
used to assess the probability of finding a particular blood type in a specific p
- Historical investigations: Blood group analysis can be used to identify remain

Limitations of blood typing

- Limited ability for identification: Many people share the same blood type, ma
identify a specific individual based on blood type alone.
- Contamination: Bloodstains can become contaminated, making it difficult to
- Degradation: Blood evidence can degrade ov[illegible]t m[illegible]ffecting the accuracy o

Blood spatter analysis

Blood spatter analysi[illegible] [illegible]orensic technique that examines the distribution, shap
to determi[illegible]eve[illegible]s that caused them. By understanding the physics of blood
recreate the[illegible]ns that led to the bloodshed.

Applications in forensics

- Crime scene reconstruction: Determining the sequence of events.
- Determining the position of the victim and attacker: Reconstructing the crim
- Identifying the type of weapon used: Analysing the shape and size of bloodst
- Corroborating or refuting witness statements: Comparing statements to the

Challenges and limitations

- Cleaning or movement of the crime scene: Can alter or destroy evidence.
- Blood volume: Small amounts of blood may not produce enough evidence fo
- Subjective interpretation: Analysts' experience and judgement play a role in

Microscopy and electron micrographs

Microscopy is an indispensable tool in forensic biology. It allows for the detailed e
materials that are often invisible to the naked eye. This microscopic analysis provi
linking suspects to crime scenes, identifying victims, and reconstructing crime eve

Applications of microscopy in forensic biology

- Hair analysis: Microscopes are used to compare hair samples from crime scen
victims. Characteristics such as colour, scale pattern, and medulla type are ex
- Fibre analysis: Microscopy is employed to compare fibres found at crime scen
carpets, or other sources. Colour, diameter, and cross-sectional shape are ke
- Bloodstain analysis: Microscopes help in identifying bloodstains, determining
blood spatter patterns to reconstruct crime scenes.
- Sperm analysis: Microscopy is used to identify and examine sperm cells, which
- Diatom analysis: Diatoms (microscopic algae) can be found in water and can
specific water source. Microscopy is used to identify and compare diatom sp
- Pollen analysis: Pollen grains can be used to determine the location and time
Microscopy is employed to identify and compare pollen types (see **Figure 3.4**

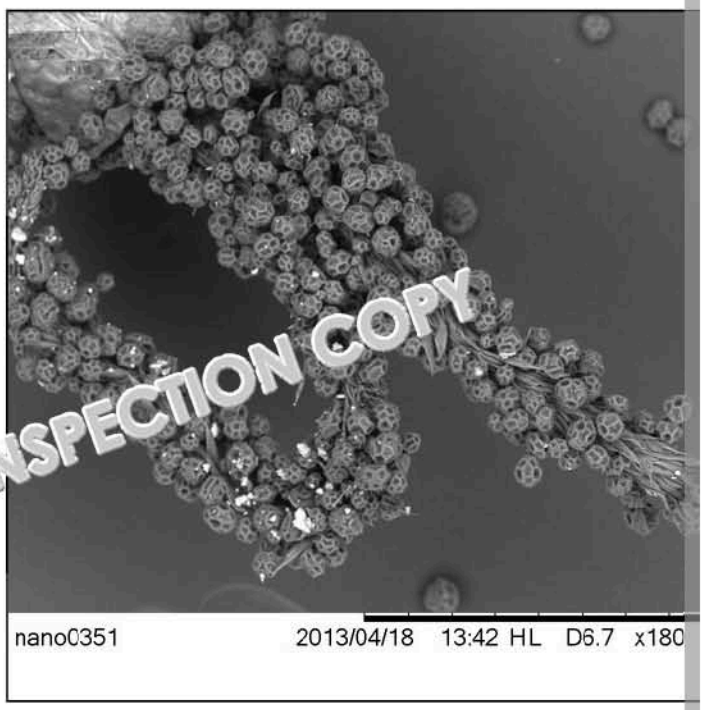


***Figure 3.4** An electron micrograph of pollen.*

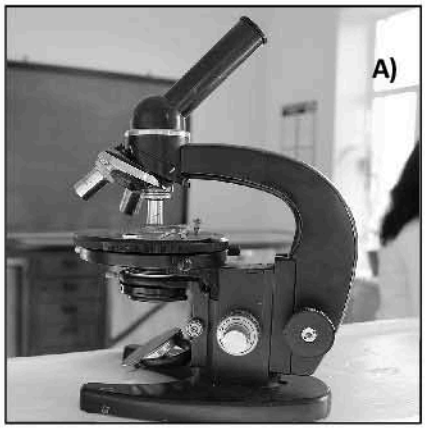
Selection and justification of appropriat

Key points covered

- Light microscopes
- Stereo microscopes
- Electron microscopes
- Evidence from humans, animals,
- Cellu[illegible]idence
- [illegible]evidence
- Organ evidence

Key features of [illegible]oscopy (2.1.1)

There are th[illegible]ain types of light microscope used in forensic biology: **compoun** (see **Figure 3.5** and **Table 3.1**).



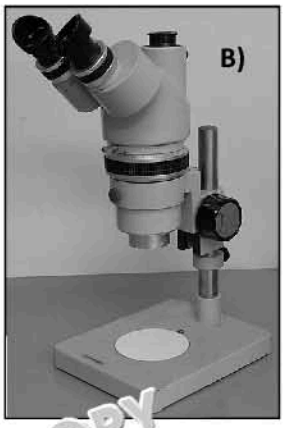


Figure 3.5 *A comparison of three diffe[illegible] type[illegible] light microscope: A) a compou B) a stereo ligh[illegible]ope, and C) a phase contrast light micros*

Table 3.1 A comparison of three different types of microscope

	Light microscope	Electron microscope
Description	A microscope that uses light to magnify a specimen to view it.	A microscope that uses beams of electrons to produce a magnified image of an object.
Use	Often used for initial and rapid examination of evidence. It is also suitable for examining larger biological samples and for comparing samples side-by-side.	Analysing extremely small particles, such as pollen grains and trace evidence. It is also used for detailed analysis of the structure of biological materials
Advantages	• Relatively inexpensive and readily available. • Simple to operate and maintain. • Portable so can be moved to crime scenes. • Can be used for li[illegible]s. • Colour [illegible]ges [illegible] be [illegible]	• Extremely high magnification and resolution. • Can be used to analyse the [illegible]ental composition of samples. • Can produce high-quality images of 3D structures.
Disadvantages	• Lower magnification and resolution compared to electron microscopes. • Difficulty in visualising very small structures.	• Expensive and complex equipment. • Samples must be prepared in a vacuum, which can damage or alter biological materials. • Black-and-white images.

Choosing the correct mount for specimens

There are two ways to prepare specimens for viewing under a light microscope. The two ways are called **wet mounts** and **dry mounts**.

The choice between a wet mount and a dry mount in forensic microscopy largely depends on the nature of the evidence being examined.

Key considerations are:

- Preservation: If the evidence needs to be preserved for future analysis or court presentation, a dry mount is usually preferred.
- Visibility: For transparent or translucent samples, a wet mount is often necessary to allow light to pass through.
- Sample integrity: Some samples might be damaged or altered by a liquid medium, making a dry mount more suitable.
- Time constraints: Wet mounts are generally quicker to prepare but might not
- Staining requirements: Sometimes specific stains are required for wet mount

A wet mount is ideal for:	A dry mount is ideal for
• Examining **organisms** such as bacteria or protozoa (though less common in forensic science) • Observing specimens that require a liquid medium to maintain their structure or function • Analysing translucent or transparent samples where light needs to pass through	• Examining solid, o • Preserving specim • Analysing samples distort or damage
Examples of wet mounts in forensic science: • Bloodstain analysis (to observe red blood cells and other cellular components) • Sperm analysis (to observe morphology and motility) • Examination of biological fluids (to identify components or contaminants)	Examples of dry mount • Hair analysis (to ob and pigmentation) • Fibre analysis (to c cross-sectional sha • Examination of soi • Analysis of gunsho

Key points covered

- Using microscopes

Use of light microscopes and ele microscopes (2.1.2)

Light microscopes and ster[illegible]copes can both be used to make measureme
usually in mic[illegible]net[illegible] µm is 1×10^{-6} m or one thousandth of a millimetre.

Microscopes[illegible]be used to detect and identify microorganisms in or on evidence
This can be used to determine the cause of death, identify suspects, and link evid

The process

1. Calibration:
   - Stage micrometer: This is a specialised slide with a calibrated scale etc
   microscopic ruler, typically in micrometres, µm.
   - Eyepiece graticule: This is a transparent scale placed in the microscope
   – it looks like a ruler with no numbers or units.
   - Overlay the stage micrometer and eyepiece graticule by focusing the n
   on the micrometer and moving the slide on the stage. Determine the **conversion factor** between the two scales for each objective lens. For
   if a 2 mm object appeared to be 20 mm under the microscope, the sca
   the microscope is 10× and the conversion fac[illegible]would be 0.1. So, to c
   a measurement from the microsc[illegible]e sca[illegible]e to the actual scale, you wo
   multiply the measurem[illegible]th[illegible]conversion factor, which in this exa

2. Mea[illegible]nt
   - [illegible]e the micrometer from the stage.
   - Place the sample on the microscope stage.
   - Use the eyepiece graticule to estimate the size of the object in eyepie
   - Apply the calibration factor to convert the eyepiece units to micrometr

Key considerations

- Accuracy: The accuracy of measurements depends on the quality of the microscope, the accuracy and condition of the stage micrometer, and the user's ability to accurately align the scales.
- Magnification: The magnification of the objective lens affects the measurement. It is essential to calibrate the eyepiece graticule for each objective.
- Sample preparation: Proper sample prepa[illegible]ra[illegible]on[illegible] crucial for accurate measurement[illegible]m[illegible]mple should be well-illuminated, free[illegible]rtef[illegible]cts and focused for accurate measur[illegible]

- Multiple m
measurer
calculate
This is to
- Calibratio
objective
- Image an
can be in
allowing f
and more

A wet mou[illegible]ade as follows:

- A drop of liquid is placed on the slide.
- The specimen is added to the liquid.
- A stain is sometimes added.
- A coverslip is carefully lowered over the specimen.

A dry mount is mad

- The specimen i
- A coverslip is c
the specimen.

Analysing observational analysis (4.1.2)

Saliva

For saliva, a visual examination should consider:

- Appearance: Saliva is typically clear, colourless and viscous. However, its app contaminants such as blood, food particles, or other bodily fluids.
- Location: Where is the saliva found? Is it on a surface, an object or a person? about the crime and how the saliva was deposited.
- Quantity: The amount of saliva present can influence the type of collection m for DNA analysis.
- Distribution: How is the saliva distributed? Is it in a pool, droplets, or smears? provide information about the deposition method.
- Associated evidence: Are there other types of evidence present, such as finge This information can help to correlate the saliva with other aspects of the cri

Blood

There are two presumptive tests for blood, as discussed on page 39. These can te crime scene.

Luminol presumptive test procedure:

1. Preparation: Luminol solution is typically prepared in a dark room.
2. Application: The solution is sprayed onto the suspected area.
3. Observation: The area is observed for a blue glow, indicating the possible pre
4. Documentation: Any luminescence is photographed or recorded (see **Figure**
5. Sample collection: If a positive result is obtained, blood samples are collected

***Figure 3.6** Luminol was sprayed onto a floorboard. Although no blood was seen a blue glow from luminol indicated the presence of blood.*

Leucomalachite green (LMG) presumptive test procedure:

1. Colourless reagent: LMG is prepared and is initially colourless.
2. Oxidation: In the presence of blood and an oxidising agent (such as hydrogen is oxidised.
3. Colour change: This oxidation process produces a vibrant blue-green colour, indi

Blood characteristics:

- Colour: Is the blood fresh (red) or dried (dark brown)?
- Texture: Is the blood liquid, clotted or dried?
- Presence of other substances: Are there any other substances mixed with the

The types of bloodstains are:

- Passive stains: Created by gravity, such as drops, flows and pools.
- Projected stains: Created by force, such as impact splatter, cast-off, and arter
- Transfer stains: Created by contact between a bloody object and a surface, such

Blood Spatter Patterns		
	High Impact	**Medium Impact**
Droplet size	less than 1 mm	between 1 mm and 4 mm
Velocity	around 30 m s^{-1}	around 7 - [illegible] m^{-1}
Example	gunshot	st[illegible]
Image		

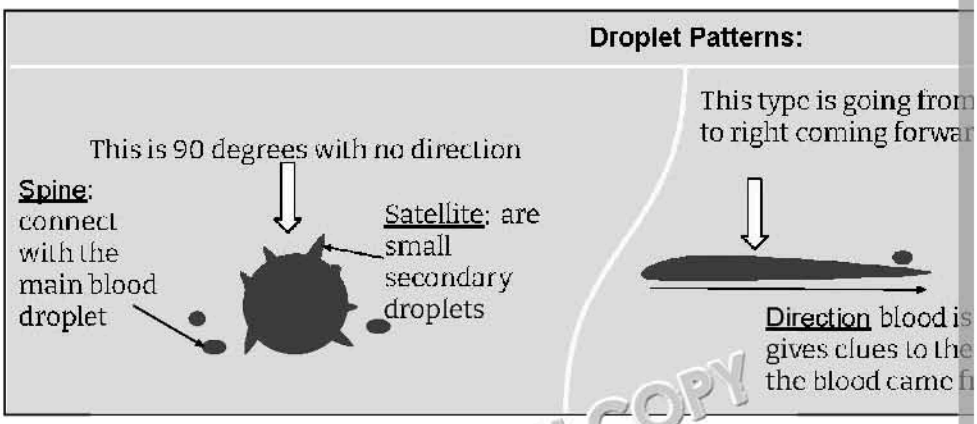


Figure 3.7 *Examples of the t[illegible]ood spatter and droplet* ***patterns from a cri***

Blood is acted on by for[illegible]s gravity, surface tension and air resistance whe
These influ[illegible]e [illegible] and size of the bloodstain as it lands on a surface (see F
patterns to [illegible]ine:

- The origin of the blood: Where did the blood come from?
- The direction of the impact: Where was the blood coming from?
- The angle of impact: At what angle did the blood hit the surface?
- The height of the origin: How high was the blood source?
- The number of blows: How many times was the victim struck?
- The movement of the victim and attacker: What were their positions?

Fingerprints and footprints

Even at the initial observation stage, forensic experts look for specific characterist

- Pattern type: Arches, loops or whorls.
- Minutiae: Unique ridge characteristics such as ridge endings, bifurcations, an comparisons of minutiae patterns, and **Figure 3.9** for a real print showing the
- General shape and size: Overall configuration of the print.

These elements provide the basis for comparison and identification.

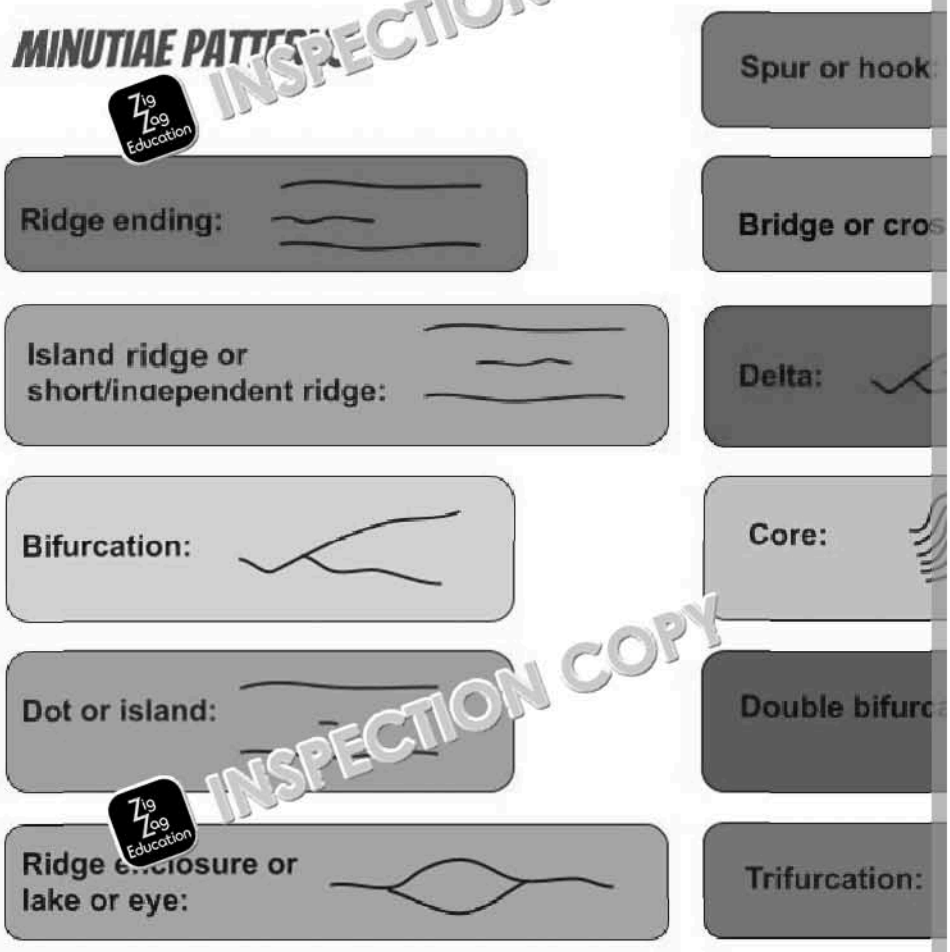


Figure 3.8 *A comparison of the different types of minutiae patterns in a*

Figure 3.9 *A fingerprint showing the different* ***minutiae patterns***

The initial observation of footprints at a crime scene is a crucial step in the forensi evidence can provide valuable information about the number of individuals prese movement, and potential points of entry or exit.

Key aspects of initial observation

- Location:
  - Where are the footprints located in relation to the crime scene?
  - Are they indoors or outdoors?
  - Are they in a specific area, such as a point of entry or exit?
- Number:
  - How many different sets of footprints are present?
  - This can indicate the number of individuals involved.
- Type:
  - Are they barefoot, shod, or a combination?
  - The shoe or boot wear can provide clues about the suspect's occupation or
- Clarity:
  - How clear are the impressions?
  - Detailed impressions are more valuable for analysis.
- Direction:
  - What is the direction of the footprints?
  - This can help determine the sequence of events.
- Depth:
  - How deep are the impressions?
  - This can indicate the weight of the person who made them.
- Size:
  - What is the approximate size of the footprints?
  - This can help estimate the height and weight of the individual.
- Pattern:
  - Are there any unique patterns or characteristics in the footprints?
  - These can be used for comparison and identification.

Other types of print

When encountering a lip print at a crime scene, forensic experts typically focus on

- Presence and location:
  - Is there a clear lip print?
  - Where is it located (e.g. glass, paper, skin)?
  - What is the surface condition (smooth, rough, porous)?
- Clarity and completeness:
  - How clear and defined is the print?
  - Is the entire lip print visible, or are parts missing?
- Colour and material:
  - What is the colour of the lip print (e.g. red lipstick, clear saliva)?
  - Is there any foreign material present (e.g. blood, dirt)?
- Pattern analysis:
  - Preliminary assessment of lip print patterns (linear, angular, or mixed).
  - Comparison with known lip print patterns for potential identification.
- Documentation:
  - Detailed photographs of the lip print from various angles.
  - Careful lifting or collecting of the print, if possible.
  - Accurate recording of the crime scene location and conditions.

Hair

Determining whether a hair sample is human or animal is a crucial first step in fo characteristics can be observed through microscopic examination which differenti **Table 3.2** and **Figure 3.10**:

Table 3.2 Characteristics of animal and human hair.

	Human hair	
Medulla	Generally thin, an (shapeless), and less than ½ the hair diameter.	Often thicker, interrupted), a the hair diame
Scale patt	In icate pattern (overlapping scales like roof shingles) (see the micrograph of a human hair in **Figure 3.11**).	More varied pa (crown-like) an
Root	Typically, club-shaped.	Highly variable the species.
Pigmentation	Generally, evenly distributed pigment.	Pigment distrib concentrated t
Other characteristics	Less variable hair shaft. Colour banding is less common.	More variable more common

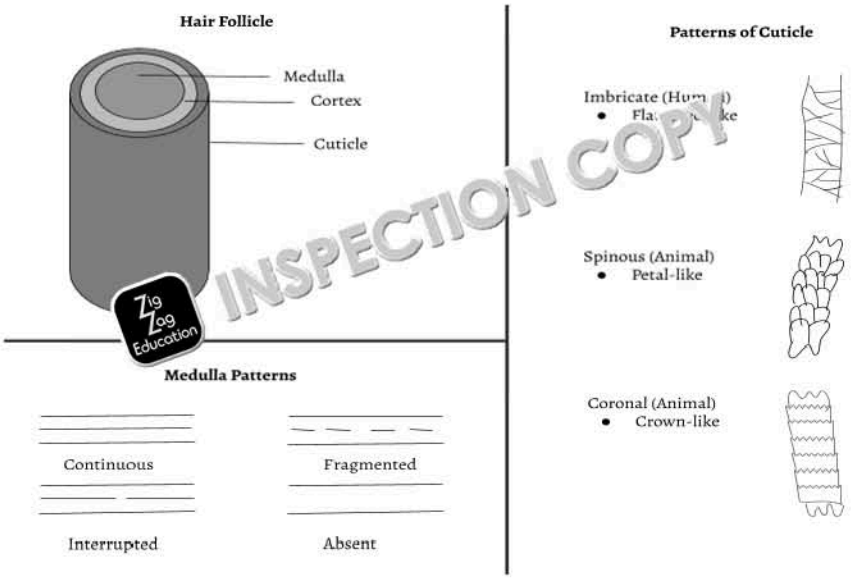


***Figure 3.10** A diagram showing a labelled human hair strand, and the different medulla and cuticle patterns.*

Formative discus ques tions:

Read the ' robbed the corner shop' on page 2. What considerations must y and skilfull m observational analytical techniques?

Key points covered

- Culturing microorganisms
- Types of microorganisms in evidence
- Detecting microorganisms in evidence
- Growing bacteria on agar
- Growing fungi
- Analysis of microor
- Importance of diat
- Limitations in scho

Preparing foren[illegible]vidence for microscopy (2.1.2.)

Staining i[illegible] mounts

Some samples, such as human skin cells or cheek cells, are transparent. That mea[illegible] microscope, very little can be seen of the cells.

Common staining techniques include the use of:

1. Methylene blue:
   - This is a basic stain that binds to negatively charged components in the cell, such as **nucleic acids** (DNA and RNA).
   - It stains the **nucleus** of the cell a dark blue colour, making it easily visible (see **Figure 3.12**).
   - It is a simple and effective stain for observing basic cell structure.
   - Useful for skin cells, cheek cells, etc.
2. Crystal violet:
   - Similar to methylene blue, it's a basic stain th[illegible]s to negatively charg
   - Provides a darker and more intense stai[illegible]methylene blue.
   - Useful for skin cells, cheek c[illegible]
   - Often used in conjun[illegible]n w[illegible]other stains in more complex staining pr
3. Immunological [illegible]
   - T[illegible]e prepared to detect certain proteins in samples such as human
   - Th[illegible]e very specific and can identify hair from one particular individua
   - They use **antibodies** attached to stains to bind to the hair proteins.

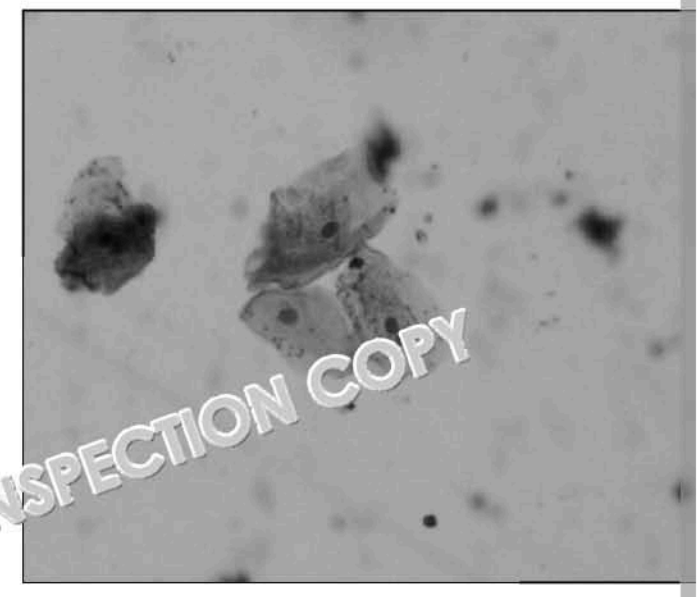


***Figure 3.12** A micrograph of a group of four human cheek cells stained with [illegible] The nucleus is visible as a darker blue dot inside the cell.*

Cell and tissue structure can be observed and measured from:

- Temporary slides – slides made for short time observations and are discarde
  Figure 3.12.
- Microscope drawings/photographs – line drawings or photographs that reco
  structures, such as cells and tissues viewed under a microscope, as seen in **Fi**
- Electron micrograph – a photo taken of an object or a specimen viewed unde
  seen in **Figure 3.13A**.
- Generalised diagrams/photographs – photo[illegible]ap[illegible]tissue not seen under a
  diagram of a blood splatter.

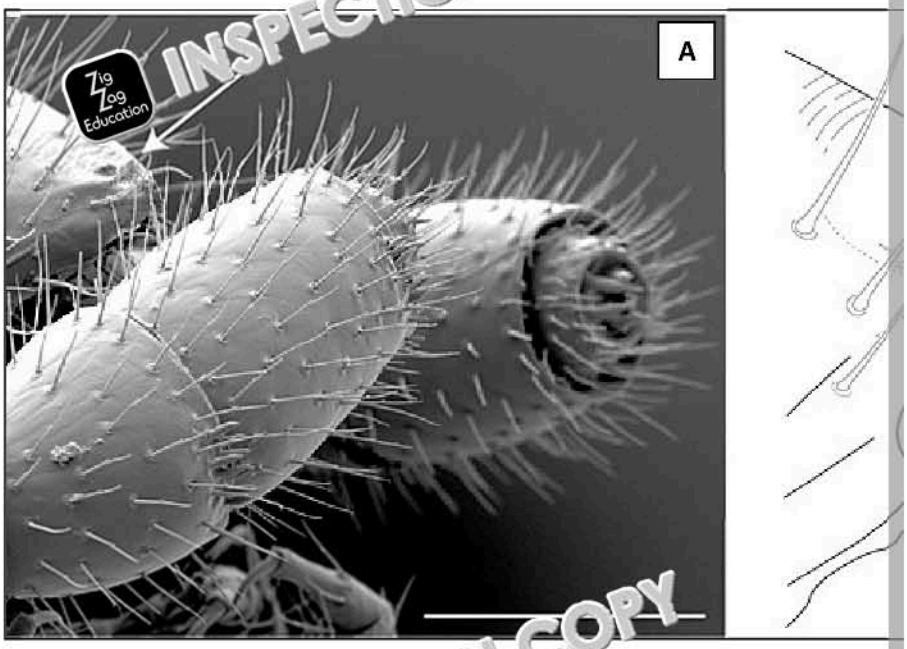


Figure 3.13 *A) A scan[illegible]micrograph of the antennae **of a millipede**, sc*
*[illegible]oscope drawing of the image seen in **A, scale bar 0.01***

Microor[illegible]ms in evidence (4.2)

The field of forensic science has made good use of microorganisms. Bacteria, viru
valuable tools in crime investigation.

Microbes

- Bacteria: such as those found in soil and in the gut; however, bacteria are al
- Fungi: such as those growing around plant roots and those that cause mild h
  - Fungi play a significant role in decomposition, helping to estimate PMI.
  - Specific fungal species can indicate the environment where a body was
  - Fungal growth patterns can provide clues about the conditions at a crim
- Algae: such as those found in rivers, lakes and canals and include the diatom
  called plankton.
  - Diatoms are microscopic algae found in [illegible]; so if a person drowns, di
    lungs and other organs.
  - The type of diatoms [illegible]can indicate the water source where drow

Bacteria ar[illegible]de[illegible]on page 17.

Apply your knowledge

Think of a situation in which bacteria, fungi or algae might be an important source of evi

Viruses

These cannot survive for long outside an organism; most are associated with disea
(bacteriophage) are found in the healthy gut and in the environment.

- Viral analysis can confirm or refute suspected diseases.
- Tracking the spread of viruses can aid in public health investigations.
- Identification of specific viral agents can be crucial in counterterrorism effort
- The presence of aquatic bacteriophage can indic[illegible]ov[illegible]ning.

The identification of ba[illegible]te[illegible] and fungi (2.3.4)

The detecti[illegible]d a[illegible]f microorganisms in forensic evidence is a rapidly evo
field. It invo[illegible]combination of traditional microbiological techniques and adva
molecular m[illegible]ods. **Isolation** and identification of microorganisms are fundamen
processes in microbiology. Bacterial and fungal cultures from the crime scene can
be compared to the cultures collected from the suspects/victims to see if there is
confirmed match. This can help to link individuals to the crime scene.

Several tools and techniques can be employed to isolate microorganisms.

A sample can be spread on **agar** to obtain isolated colonies which can then be
picked off and cultured separately (as seen in **Figure 3.14**).

***Figure 3.14** An enriched agar plate with **colonies** of microorganisms present.*

Once isolated, microorganisms can be identified using a combination of methods,
molecular tests and techniques based on observable characteristics (see **Figure 3.**

***Figure 3.15** A scientist observing the colony appearance on culture*

Bacteria

Traditional microbiological methods of detection:

- Culture-based methods: Involve isolating and growing microorganisms on sp
  While time-consuming, they can provide valuable information about the typ
  organism present.
- Microscopy: Used to examine the **morphology** of microorganisms, aiding
  in identification.

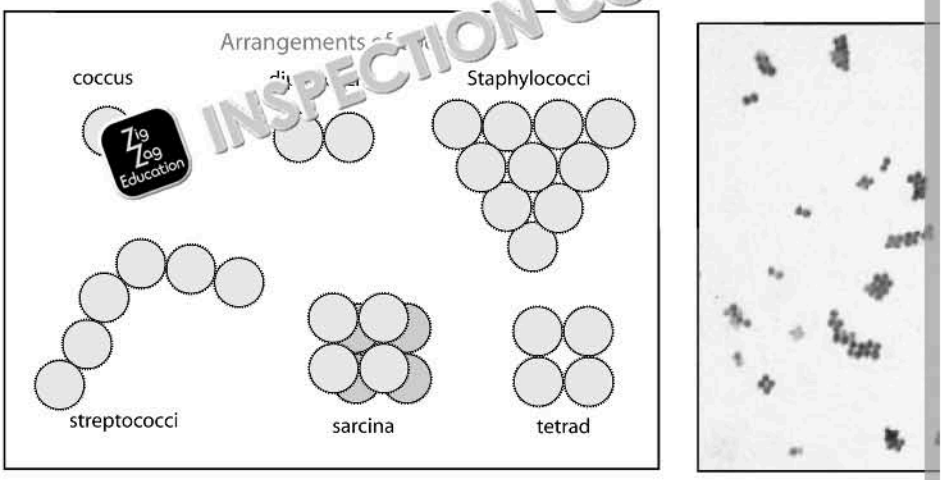


***Figure 3.16** A diagram showing the morphology of the cocci bacteria (left) and a mi*

Molecular methods of detection, offering higher sensitivity and specificity:

- Polymerase chain reaction (PCR): Amplifies specific DNA sequences, enabling
  amounts of microbial DNA.
- Real-time PCR: Quantifies the amount of tar N providing information a
  of microorganisms.
- DNA sequencing: Determin plete genetic sequence of a microorga
  identification and

Viruses

Viruses cannot be grown outside of living cells, so cannot be cultured on agar, like
identified by one or more of these techniques:

- Electron microscopy: This can narrow down the type of virus to one of a few
- Immunological analysis: This uses antibodies labelled with dyes or stains spe
- Nucleotide sequencing: The sequence of the virus genome and whether it is
  stranded will identify the virus.

Fungi

Fungi are usually identified by macroscopic and microscopic methods:

- Colony morphology: Observing the appearance of fungal colonies on culture
  as colour, texture and growth pattern.
- Microscopic examination: Studying the struc ure of fungal hyphae, spores,
  and reproductive structures using li m croscopy.
- Physiological and biochem tests: Assessing fungal growth on different
  media, their abilit specific substrates, and their **metabolic** product

These mole echniques provide more precise and rapid identification:

- DNA sequencing: Determining the nucleotide sequence of specific fungal ge
  transcribed spacer, which is unique to each fungal type) region, for compari
- Polymerase chain reaction (PCR): Amplifying specific DNA sequences for dete

Diatoms

Diatoms are identified by either microscopic, morphological or molecular method

- Microscopy:
  - Light microscopy: The most common method, used to examine the morph of cell walls (frustules), including shape, symmetry, and valve pattern.
  - Electron microscopy: Provides detailed images of cell wall (frustule) stru revealing fine details often invisible under li[illegible]scopy.
- Morphological analysis:
  - Comparison of observed [illegible] features with reference materials and t
  - Detailed measu[illegible] cell wall (frustule) dimensions and patterns.
- Molec[illegible]ch[illegible]:
  - Di[illegible]uencing: Used for species-level identification and phylogenetic
  - PCR: Amplification of specific DNA regions for diatom detection and qua

Culturing microorganisms safely and effectively (2.3.2)

Culturing microorganisms comes with several risks, such as the potential to grow can cause illness. However, it is safe provided some basic guidelines are followed.

General safety practices

- Aseptic technique: Use sterile equipment and maintain a sterile environment (e.g. wipe surfaces clean with disinfectant). This is incredibly important to prevent contamination.
- Hand hygiene: Always wash hands thoroughly with soap and water before and after handling microorganisms.
- Personal protective equipment (PPE): Wear [illegible], gloves, and safety glasses when working with microor[illegible].
- Biological safety cabinets (PSC): [illegible]losed laboratory workspaces that are well ventilated. Th[illegible]u to protect people and the environment from hazard[illegible]at[illegible] (see **Figure 3.17**).
- Work a[illegible]sinfect your work area before and after use with 70 % ethanol in water.
- Waste disposal: Properly dispose of all contaminated materials according to laboratory protocols. Use dedicated biohazard bins if appropriate.
- Emergency procedures: Familiarise yourself with emergency procedures, including fire safety and chemical spills.

Specific safety considerations

- Biological containment: Observe the containment regulations for the organis four levels of containment, from Level 1 for non-pathogenic organisms up to agents that pose a high risk of lethal infection through aerosol transmission, Marburg virus.
- Culture medium: Prepare culture medium accordin[illegible]stablished protocols
- Incubation: Incubate cultures at appropriate tem[illegible]atures and for specified
- Contamination prevention: Work near a [illegible]en burner to create an upward current of air th[illegible]elo[illegible]duce contamination.
- Fumigation: If a de[illegible]eb is used for microbiology, then it [illegible]d b[illegible]odically fumigated to kill any organis[illegible]t may have escaped.
- Avoid mouth pipetting: Use pipette bulbs or mechanical pipettes instead.
- No eating or drinking: Refrain from eating, drinking, or applying cosmetics in the laboratory.

- Labelli
  micro
- Storag
  conta
- Risk a
  before
  identif
  contro

Culturing bacteria on agar plates (2.3.3)

Agar plates are a standard tool in microbiology for cultivating and studying bacter
Petri dish filled with a substrate gel called agar, which provides a solid growth me
Various nutrients can be added to the agar according to the organisms being cultu

The process

1. Preparation of agar plates:
   - Prepare the desired ag[illegible] based on the bacteria you want to c
     dissolving solid [illegible] nutrients in tap water.
   - St[illegible] medium in an autoclave at over 100 °C for about 15 m
   - [illegible] cool to around 45 °C so it remains liquid but will not melt plas
   - P[illegible] the molten agar into sterilised Petri dishes.
   - Allow the agar to solidify completely in a fridge or at room temperatur

2. Inoculation:
   - Sterilise your inoculation tool (e.g. loop or swab) by passing it through
     the Bunsen burner for 10 seconds. Allow to cool for 15 seconds before
   - Obtain a sample of bacteria from a non-pathogenic, approved source (
     environment, or clinical specimen). Safety note: Do not collect samples
     animal sources (e.g. pet cage) or bodily fluids (e.g. saliva) to minimise t
   - Transfer a small amount of the sample to the agar plate using the steri
   - Common inoculation techniques include streaking, spreading, and pou

3. Incubation:
   - Seal the agar plate to pr[illegible]ntamination. Apply adhesive tape aro
     and the lid. Leav[illegible] gap in the sealing of plates in order to avoid
     mo[illegible] fav[illegible] to pathogens.
   - [illegible]e plate upside down so the agar is uppermost. This prevents co
     c[illegible]he agar surface.
   - Incubate the plate at the optimal temperature of 30 °C for bacterial gr
     culturing pathogens.
   - The incubation time varies depending on the bacteria being cultured, t
     24–48 hours.

4. Observation:
   - After incubation, examine the agar plate for bacterial growth.
   - Observe colony morphology (shape, size, colour, texture) to help ident
   - Keep Petri dishes closed so cultured organisms do not enter the enviro
     opened to pick colonies for regrowth, then do so [illegible]nder aseptic conditi
   - Dispose of cultures in sealed agar plates [illegible] a [illegible]hazard bin or in a seale

Ways of growing bacteria and fungi on agar plates

There are three main ways to grow bacteria or fungi on agar plates: streak plates,

Streak plates: Prepared by using a sterile loop to make streaks of culture into th
Each successive set of lines will have fewer organisms so more likely to form sep

1. Sterilise the inoculating loop: This is typically done by flaming the metal loo allowing it to cool.
2. Obtain a sample: Using the cooled loop, obtain a small amount of the bacteri
3. Streak the first quadrant: Ir[illegible] the first quadrant of the agar plate with back-and-forth str[illegible]
4. Sterili[illegible] loop again.
5. Strea[illegible]econd quadrant: Drag the loop through a small portion of the fi the second quadrant.
6. Repeat: Repeat the process for the third and fourth quadrants, sterilising the

Lawn plates: So-called because the organisms cover the surface of the plate eve sometimes called spread plates.

1. Prepare your agar plate: Use a suitable nutrient agar for your bacterial spec
2. Prepare your bacterial culture: Ensure you have a liquid culture with a suffi
3. Sterilise equipment: Use a sterile spreader (glass 'hockey stick') or cotton swa
4. Inoculate the plate: Dip a sterile cotton swab into the bacterial culture and of the agar plate. Alternatively, use a dropping pipette to add one drop of t of the agar – this must be done in aseptic conditions as the bursting of the pipette creates an aerosol of organisms.
5. Spread the organisms: Use the sterile spreader to spread the culture all ove end of the spreader to contact the edge of one side and turn the plate to e way out to the edge.
6. Incubate: Incubate the plate at the optimal temperature for bacterial growt

Pour plat[illegible]ed because the organisms are mixed with the agar and poured

1. Prepar[illegible]your agar plate: Use a suitable nutrient agar for your bacterial spec
2. Prepare your bacterial culture: Ensure you have a liquid culture with a suffi
3. Mix with agar: Mix some of the liquid culture with the agar that has cooled organisms yet has not solidified.
4. Pour: Pour the culture-agar mix into an empty sterile Petri dish.
5. Incubate: Incubate the plate at the optimal temperature for bacterial grow

Identification of bacteria and fungi (2.3.4)

Bacteria are broadly classified by shape and by the way they take up a particular s

By shape, viewed under the microscope most bacteria are either:

- Rods: Also called bacilli, these look like microscopic sausage-shaped objects.
- Cocci: These are spherical and exist in strips or connected sphere

By **Gram stain** bacteria are either:

- Gram-positive: These have a thick cell wall, so retain crystal violet stain well. under the microscope.
- Gram-negative: These have a thin cell wall, so lose the stain. They appear pin as they are counterstained with red safranin.

These descriptions are used together, so bacteria are described as, for example, G

Gram stain procedure

The Gram stain is a crucial technique in microbiology used to differentiate bacteri
Gram-positive and Gram-negative. This classification is based on the differences i

Materials needed:

- Bacterial culture
- Clean glass slides
- Inoculation loop
- Crystal violet
- Gram's iodine
- Decolouriser (ethanol / acetone / propanone)
- Safranin
- Water
- Bunsen burner
- Microscope with oil immersion lens

Procedure:

1. Prepare the smear:
   - Sterilise the inoculation loop by passing it through a Bunsen burner fla
   - Obtain a small amount of bacterial culture and spread it evenly on a cl
   - Allow the smear to air dry completely.
   - Heat-fix the smear by passing the slide through a Bunsen burner flame

2. Apply the primary stain:
   - Cover the smear with crystal violet for one minute.
   - Rinse the slide gently with water.

3. Apply the mordant:
   - Cover the smear with Gram's iodine for one minute.
   - Rinse the slide gently with water.

4. Decolourisation:
   - Rapidly decolourise the smear by washing it with ethanol or acetone u
   - This step is critical and should be timed correctly. Over-decolourisatio bacteria appearing Gram negative.

5. Counterstain:
   - Cover the smear with safranin for one minute.
   - Rinse the slide gently with water.

6. Air dry:
   - Allow the slide to air dry completely.

7. Microscopic examination:
   - Add a drop of oil immersion oil to the smear.
   - Place the slide under the oil immersion lens of a microscope.
   - The shape of the bacteria will also be evident: rods or cocci.

Results:

- Gram-positive bacteria will appear purple under the microscope.
- Gram-negative bacteria will appear pink or red under the microscope.

Colony morphology

The appearance of bacterial and fungal colonies on an agar plate can also be used

Colony morphology is the visual appearance of bacterial and fungal colonies grow
While it's not a definitive method, it can be a valuable initial step in bacterial and
narrow down the possibilities.

Key characteristics of colony morphology are:

- Shape: Circular, irregular, punctif[illegible] filamentous, rhizoid (root-like)
- Size: Diameter of the colo[illegible]
- Edge (margin): Ent[illegible]ulate, lobate, filamentous, curled
- Elevati[illegible]t, [illegible]sed, convex, umbonate (button-like), crateriform
- Colour: [illegible]ntation of the colony and surrounding medium
- Opacity: Transparent, translucent, opaque
- Surface: Smooth, rough, wrinkled, glistening, mucoid
- Consistency: Butyrous (butter-like), mucoid (sticky), dry, brittle

The morphology of a colony can be checked against reference samples or against

Selective and differential growth media

Selective and differential media are crucial tools in microbiology for isolating and

Selective media

Selective media inhibit the growth of certain microorganisms while allowing other
incorporating specific inhibitory agents into the media.

- Examples of selective agents:
  - Bile salts: Inhibit Gram-positi[illegible]ba[illegible]ia
  - Crystal violet: Inhibit[illegible]Gram positive bacteria
  - Antibiotics: In[illegible]t specific bacteria
  - H[illegible] co[illegible]centration: Inhibits most bacteria except staphylococci
- Examp[illegible]elective media:
  - MacConkey agar: Selects for Gram-negative bacteria
  - Mannitol salt agar (MSA): Selects for Staphylococcus species
  - Eosin methylene blue (EMB) agar: Selects for Gram-negative bacteria

Differential media

Differential media allow the visual differentiation of microorganisms based on the
characteristics. This is often achieved by incorporating specific substrates or indic

- Examples of differential characteristics:
  - Lactose fermentation: Produces acid and sometimes gas
  - Haemolysis: Ability to lyse red blood cells
  - Hydrogen sulfide production
  - Urease production
- Examples of differential media:
  - MacConkey agar: Differentiate[illegible]e fermenters from non-lactose fe
  - Mannitol salt agar (M[illegible]): D[illegible]rentiates mannitol fermenters (yellow co
    (red colonies)
  - B[illegible]ar[illegible]rentiates bacteria based on haemolytic patterns (alpha,
  - Ed[illegible]thylene blue (EMB) agar: Differentiates lactose fermenters fro
    coliforms from other Gram-negative bacteria

DNA analysis

DNA analysis has revolutionised the field of microbiology, providing a rapid, accur
for bacterial identification, but the technique is not available in all labs as it requir
trained personnel.

Further your knowledge

16S rRNA gene sequencing is the standard method for b[illegible]al identification. The 16S r
conserved region found in all bacteria. By sequencing this gene and comparing it to a da
identified to the species level.

Limitations [illegible] with microorganisms in schools

Microbiolog[illegible]astly wide and continually expanding subject that can be studie
level for a period of 3–4 years full-time in dedicated laboratories. Therefore, carry
comes with certain limitations.

- Resource constraints
  - Equipment: Specialised equipment such as autoclaves, large incubators,
    can be expensive and requires maintenance; electron microscopes will p
  - Reagents and media: The cost of culture media, stains, and other reagen
    many schools.
  - Laboratory space: Dedicated microbiology laboratories with proper vent
    often unavailable.
  - Biological containment: Labs and facilities within them are only suitable
    categories of biological containment so restricting the types of organism
  - Tissue culture: The routine culture of animal cells for growth of viruses is
  - DNA work: Techniques such as DNA sequencing and PCR will not usually
- Safety concerns
  - Pathogens: Working with poten[illegible]al microorganisms poses risk
  - Contamination: Preventing [illegible]contamination between experiments c
  - Waste disposal: [illegible]posal of biological waste requires specific protoc
- Time c[illegible]int
  - Cu[illegible]m pressure: Limited teaching time for science subjects often re
    microbiology studies.
  - Experiment duration: Many microbiological experiments require long in
    checks, which can be impractical within a school timetable.
- Skill and knowledge gaps
  - Teacher expertise: Not all science teachers have specialised training in m
  - Student understanding: Basic concepts of biology and chemistry might b
    microbiology topics.
  - Aseptic techniques: These may not be perfected to the level required to
    working in the lab.
- Ethical considerations
  - Animal experiments: Using animals in microbiology experiments raises e
    not be licensed for such work.
  - Human samples: Obtaining and ha[illegible]ing human samples for analysis ca

Despite these challenges, many schools incorporate microbiology into their curric
experiments, virtual lab[illegible]s, or external collaborations.

Your turn

Create a venn diagram comparing and contrasting the work which can be done in s
that which would be done by professional forensic biologists. Think about how thi
on the reliability and validity of any work you produce.

Maintaining the integrity of the ev

Key points covered

- Tampering with and destroying evidence
- Evaluating the chain of evidence
- Evaluating preserv

Tampering with physical evid

Evidence is often transpo en different laboratories and departments, pr
person to del ate y, alter, conceal or remove evidence. A person is also
physical evi f they knowingly present or offer false physical evidence.

Evaluating the chain of evidence

It is important that the chain of evidence is regularly evaluated to determine its ef
investigation and to verify that the evidence is legally sound (see **Figure 3.18**). If th
any point, the evidence may be excluded from court.

Questions to ask and answer when evaluating the chain of evidence:

Collection:
Has the date, time, person collecting the evidence and location of collection been accurately recorded?
Has the evidence been handled by any unauthorised or undocumented persons?

Pack
Has a description of ging materials used and h dence was secured been accurately documented?
W evidence secured with tamper-evident seals?

Has an accura
analysed the ev
results of the

Is th
trans

Transportation:
Is there an accurate record of who transported the evidence, the date, time, and the mode of transportation?
Was the evidence secured somewhere where unauthorised persons could not gain access?

Storage:
Has the information about the location, access controls, and environmental conditions of the storage facility been documented accu ely?
Was the evidence stored somewh e unauthorised persons co d not a access?

3.18 Questions to ask and answer when evaluating the chain of

Effectiveness of preservation methods

Preserving the evidence from the point of recovery is vital for preventing contami
the evidence.

It is important to evaluate the effectiveness of these methods to ensure the evide

Questions to ask and answer when evaluating:

- What preservation methods worked?
- Was any evidence contaminated or de[illegible]ed during any stage of the investi
- What was the cause of c[illegible]min[illegible]ion or destruction?
- What would yo[illegible]d[illegible]fferently next time?

Recall questions

1. What should be included in the chain of evidence do

Recording results

! Key points covered

- Conclusions from evidence
- Possibility of bias in conclusions
- Quality of data
- Presentation of evi

Independent variable – the variable that is changed i[illegible] th[illegible]inv[illegible]gation.

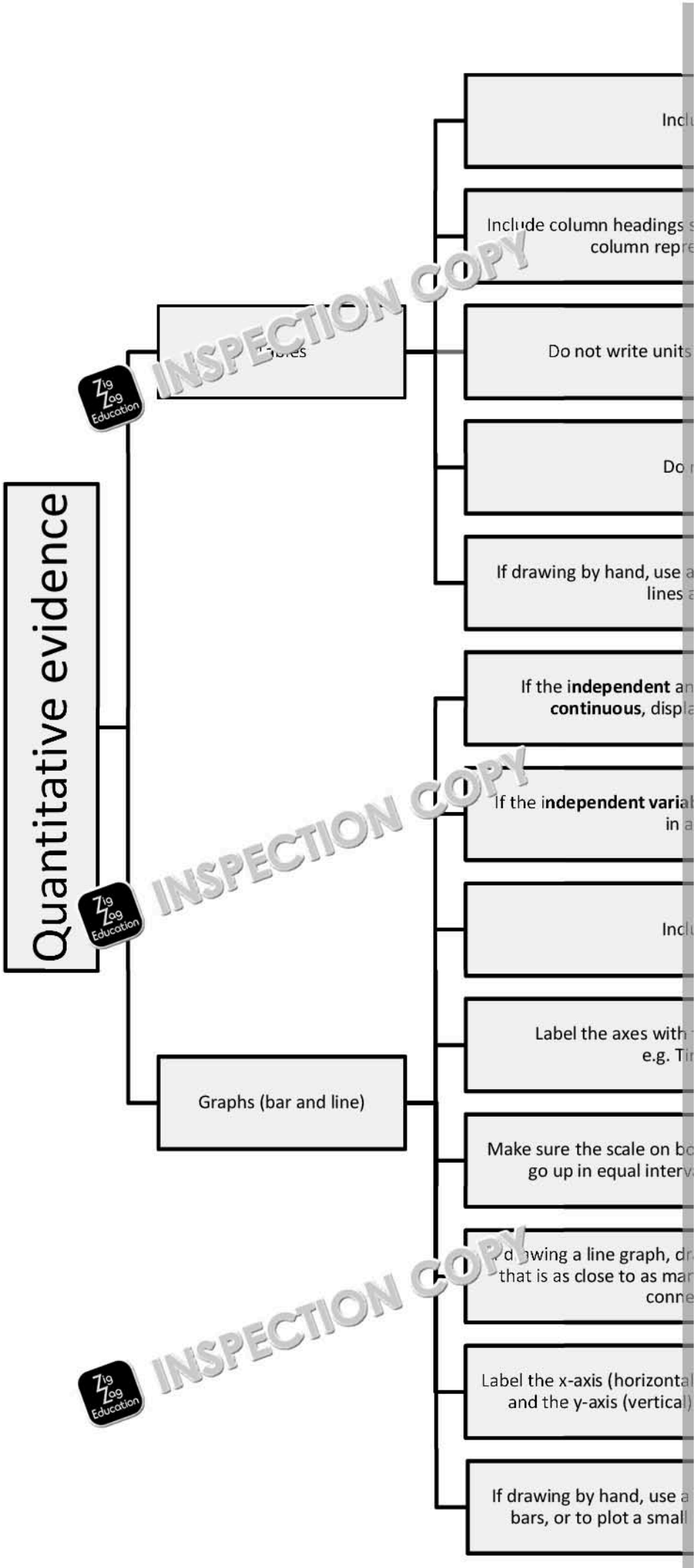
Dependent variable – the variable that c[illegible]s in response to the independent variable and is th

Categoric data – data that [illegible] into groups using labels or names.

Continuou[illegible] – n[illegible]erical data that can take any value.

Qualitative evidence

Photographs and videos	Used to capture and preserve visual evidence
Drawings	Create a visual representation of the crime scene to complement photographs
Crime scene [illegible]s	Serve as a detailed record of everything observed and done at the crime scene



Identifying individuals from evid

Key points covered

- Communicating results of ana
- What a forensic biologist does

Commu ing results of analysis (4.3.2)

Forensic biologists play a crucial role in the justice system, but their work is only v effectively communicated. There are primarily two main channels for this commu

1. Written reports, which should:
   - Be detailed and comprehensive: These reports outline the methodologi conclusions drawn from the forensic analysis.
   - Be audience-specific: The level of detail and technical jargon can vary de audience (law enforcement, lawyers, judges, or other scientists).
   - Adhere to legal requirements: Reports must adhere to specific legal and
2. Verbal testimony, which should:
   - Be clear and concise: Forensic scientists often testify in court, where the scientific concepts to a non-expert audience (jury).
   - Be persuasive: The ability to effectively communicate the significance of
   - Stand up to cross-examination: Forensic scientists must be prepared to conclusions under rigorous questioning.

Key considerations for effective co ni ation:

- Clarity: Using plain lan explain complex concepts.
- Objectivit Pre findings without personal bias.
- Accura ur g that information is correct and precise.
- Releva ocusing on information that is pertinent to the case.
- Visual aids: Using diagrams, charts, or photographs to enhance understandin

What a forensic scientist does and does not makes judgements or

Forensic biologists make crucial judgements based on the evidence they analyse. significantly impact legal proceedings. Here are some key areas where they make

- Evidence analysis and interpretation
  - Identification: Determining the nature of a substance (e.g. blood, saliva)
  - Comparison: Matching evidence to a known source (e.g. fingerprints, DN
  - Reconstruction: Determining the sequence of events based on evidence patt
- Evaluation of evidence quality
  - Reliability: Assessing the condition and integrity of evidence.
  - Sufficiency: Determining whether there is en e idence to draw a co
  - Admissibility: Deciding whether the evidence meets legal standards for
- Estimation of time frames
  - Post-mortem interval: Estimating the time since death based on factor decomposition, insect activity, and rigor mortis.
  - D es n: Estimating the time of drug consumption based on drug
- Assessm f probability
  - Match probability: Calculating the likelihood of a random match for evide
  - Error rates: Estimating the potential for false positives or negatives in an
- Testimony and communication
  - Clarity and objectivity: Presenting complex scientific information in unde
  - Defence against challenges: Responding to opposing counsel's question

These judgements are based on scientific knowledge, experience, and established involve a degree of subjective interpretation, which is why the adversarial legal sy cross-examination.

The role of a forensic scientist is to provide objective data and analysis. They do n guilt or innocence. Their job is to present the facts, and it is up to the legal system the context of the case.

Specifically, forensic scientists do not:

- Determine guilt or innocence – that is the role of the judge or jury.
- Offer legal opinions – their expertise is in science, not law.
- Make assumptions about the case: They should base their findings solely on t

Formative questions:

Read the scenario 'Who robbed the corner shop' on page 2.

Select two pieces of evidence from the crime scene. Use this evidence to suggest which

Suggest the relative importance of the results from the analytical techniques to the inves

Consider the following:

- The type of evidence: class evidence or individual evidence
- The relative importance of each type of evidence

Validity and limitations of techni

Key points covered

- Advantages and disadvantages of forensic techniques
- Evaluation of

Advantages and disadvantages of forensic techniques (2

Forensic technic	Advantages	
Appropriate staining	• Makes it easier to observe the cells and their components under a microscope. • Immunological stains can detect certain proteins and are very specific, useful in identifying hair from a particular individual.	• Some samp by the stain
Microscopy	• It can help identify and compare pieces of evidence that are too small to be seen with the naked eye. • Microscopes can identify pollen grains and spores, to determine specific locations or time frames. • Microscopy enables evidence to be analysed in great detail.	• Interpretati is subjective
Culturing microorganisms	• Comparing microorganisms cultured from the crime scene to cultures collected from the suspects' skin can help link individuals to the crime scene. • Culturing microorganisms can help determine the cause of death.	• Culturing m time and re • It can be ex • Requires ve technique t
Colon morphol	• It is cheap.	• It is not a d
Selective and differential media	• It can give results quickly.	• It has low s more false • Requires a the techniq
Serology	• Serology can be useful in establishing the sequence of events. • It can be used to exonerate innocent suspects.	• Serological contaminate • Biological m making ana • Often, only evidence ar • The increas reduced the
DNA ana	• High specificity and sensitivity: Accurate identification to the species or even strain level. • Speed of results: Faster than traditional culture-based methods. • Detection of unculturable bacteria: Can identify bacteria that cannot be grown in the laboratory. • Comprehensive information: Provides insights into antibiotic resistance, virulence factors, and other genetic traits.	• DNA can de environmen • DNA eviden • Time-consu • Sample size

Evaluation of the quality of evidence (4.3)

The quality of evidence is assessed and evaluated in terms of its accuracy, validity

Accuracy, **validity** and **precision** are critical concepts in forensic science, ensuring legal proceedings.

Accuracy	Validity
• Definition: The degree to which a measurement or an observation conforms to the true value of the quantity being measured. • Relevance: In forensics, it refers to the correctness of identifying a substance, a person, or an event. • Example: A DNA profile accurately matching a suspect, or a blood type correctly identified.	• Definition: The extent to which a test or measurement measures what it purports to measure. • Relevance: In forensics, it ensures that the evidence collected and analysed is relevant to the case. • Example: A DNA test designed to identify individuals is valid for that purpose, but not for determining blood type.

Interplay of accuracy and precision

- Accurate but not precise: A measurement can be close to the true value but
- Precise but not accurate: Measurements can be consistent but consistently
- Accurate and precise: The ideal situation where measurements are both cor
- Neither accurate nor precise: Measurements are both incorrect and inconsist

Accuracy, validity and precision can be maximised by:

- Standardisation: Adhering to established protocols and procedures.
- Quality control: Implementing measures to monitor and maintain data qualit
- Proficiency testing: Regularly assessing laboratory performance.
- Calibration: Ensuring equipment is accurate and precise.
- Chain of evidence: Maintaining rigorous control over evidence handling.
- Expert witness testimony: Providing clear and unbiased explanations of resul

Limitations of a single piece of evidence (4.3.1)

A single piece of evidence, no matter how compelling it may seem, is rarely suffici
reasonable doubt. This is due to several inherent limitations:

1. Context-dependence:
   - A single piece of evidence is often more mean[illegible] when considered i
   - The interpretation of a single piece of evi[illegible]e can be subjective and

2. Potential for conta[illegible] destruction:
   - If [illegible]ch[illegible] [illegible]idence is broken or compromised, the reliability of the
   - [illegible]me, evidence can deteriorate, making it less useful or even inad
   - E[illegible]ence might be tampered with, through planting false evidence, alt
     destroying evidence.

3. False positives and negatives:
   - Human error or technical issues can lead to incorrect results.
   - Even with advanced techniques, there is always a chance of a false pos
     False positives and negatives can be minimised by using:
     - Strict procedures for evidence handling, analysis and interpretation
     - Using known samples to validate test results and identify potential
     - Employing multiple independent tests to verify initial findings.
     - Calculating the probability of a random match using statistical analy
     - Utilising techniques with high detection limits to ensure evidence is
     - Adequate sample size: Collecting sufficient [illegible]erial for analysis.
     - Protecting evidence from degradati[illegible]
     - Relying on skilled professi[illegible] i[illegible]rpret results accurately.

4. Lack of [illegible]ecifi[illegible]
   - [illegible]yp[illegible]s of evidence, such as fingerprints or DNA, can be found in n
   - W[illegible]t additional information, it can be difficult to link a piece of evi
     person or event.

5. Subjectivity in interpretation:
   - The interpretation of evidence can be influenced by the expert's own b
   - Jurors may misunderstand or overvalue a single piece of evidence.

For these reasons, forensic investigations typically gather and analyse multiple pie
strong case. The corroboration of different types of evidence significantly increase
value of the overall findings.

Formative discussion questions:

Read the scenario 'Who robbed the co[illegible] sh[illegible] on page 2.

Select one piece of evi[illegible] from the 'corner shop robbery' and discuss the validity of th
planned t[illegible]efe[illegible] your earlier answers in the planning section).

Glossary

Accuracy – the degree to which a measurement or an observation conforms to t being measured.

Agar – a nutrient-rich gel-like substance also known as culture medium, used a and fungi.

Antibody – a protein that helps the body fight infection.

Archaeology – using human remains to study human history.

Asphyxia – when the body is deprived of oxygen.

Bindle – a piece of paper that is folded in a certain way to contain and transport

Biocrime – the use of microorganisms with the intention to cause harm to huma often motivated by revenge or the desire for monetary gain.

Biological – relating to living beings.

Biosecurity – a comprehensive set of practices and procedures aimed at prevent misuse, or intentional misuse of biological materials.

Bioterrorism – the use of microorganisms with the intention to cause harm to hu often motivated by political, religious or ideological beliefs.

Categoric data – data that is organised into groups using labels or names.

Cause of death – identifying the specific injury or disease that led to death.

Cell wall (frustule) – the outer layer of a plant, bacterial or fungal cell that provid

Circumstantial evidence – indirect evidence that implies a fact but does not dire

Class evidence – general evidence that can narrow down a list of individuals or o general cl... cannot be used to identify a specific individual.

Colony – a group of microorganisms that can be seen.

Confirmatory tests – definitively identify the type of bodily fluid.

Continuous data – numerical data that can take any value.

Conversion factor – a number used to change a measurement from one unit to a

Cordon log – a document detailing the time, date, who enters the crime scene, a

Corroborate – to provide support to a statement or theory.

Dependent variable – the variable that changes in response to the independent is measured.

Direct evidence – first-hand evidence, such as eyewitness testimony.

DNA – a molecule that carries the genetic information of a person and almost all

DNA profile – a pattern of DNA used to identify an individual or a sample of bodi

Double swabbing – a method which involves wet swabbing and dry swabb of DNA evi...

Dry mount – a preparation where a solid specimen is placed directly on a micros with a **coverslip**.

Evidence – material or information collected to investigate and prove a crime wa

Excavate – to dig out and remove from the ground.

Exonerate – free someone from blame.

Fingerprinting – the process of using unique characteristics to identify an organis

Independent variable – the variable that is changed in the investigation.

Individual evidence – evidence that can narrow dow[illegible] to a single individu identify a specific suspect.

Isolation – separating a single ty[illegible] organism from a mixed population.

Liability – the legal [illegible] bility for a criminal act.

Luminol – [illegible]ical compound that emits a [illegible]rescence when it comes i

Manner of death – classifying the [illegible]omicide, suicide, accident, natural, c

Metabolism – the c[illegible]l r[illegible]ctions that take place inside the body that release

Microbial – relating to microorganisms.

Microbiome – a community of microorganisms in a specific environment.

Microorganism – a living thing that can only be seen through a microscope.

Morphology – studying the organism's shape, size and structure.

Necrobiome – the community of microorganisms on and around a decomposing

Nucleic acids – large biological molecules involved in storing and expressing gene

Nucleotide – a building block of DNA.

Nucleus – an organelle that stores the cell's DNA

Organisms – living things.

Pathogen – a micr[illegible] that causes disease.

Perimorte[illegible] [illegible]nts that took place at the ti[illegible] of [illegible]th.

Perpetrator – a person carrying [illegible] [illegible]gal act.

Post-mortem interv[illegible]) - [illegible]etermining how long the person has been dead f

Precision – the degree to which repeated measurements or observations show t

Presumptive tests – preliminary tests used to indicate the possible presence of a

Probative – having the quality to provide proof.

Rigor mortis – when the body's muscles stiffen after death.

Scene of crime officer (SOCO) – an officer employed by the police who collects e

Suspect – someone identified as a person who *might* hav[illegible]mmitted a crime.

Testify – to give a formal statement under oa[illegible] [illegible]ge or jury to help establis

Testimony – a formal statement g[illegible] [illegible]ourt.

Validity – the exte[illegible] [illegible]h a test or measurement mea[illegible] [illegible]t it purports

Vial – a sm[illegible]tainer, typically made of gla[illegible]d [illegible] to hold liquids.

Wet mount – a temporary prep[illegible] [illegible] specimen in a liquid medium, usually slide and a coverslip