FORENSIC SCIENCE

DNA, Fingerprints & Trace Evidence

A 3-Week Unit for Grades 9–12

15 Lesson Plans • Hands-On Labs • Practice Activities • Unit Assessment

DNA Extraction • RFLP/STR Profiling • Fingerprint Classification • Hair & Fiber Analysis • CODIS Database

UM Printables

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UNIT OVERVIEW

Course: Forensic Science — DNA, Fingerprints & Trace Evidence

Grade Level: 9–12

Duration: 3 Weeks (15 Lessons, approximately 50 minutes each)

Prerequisites: Basic biology knowledge (cell structure, DNA awareness)

Unit Description

This three-week unit introduces students to the fundamental principles of forensic evidence analysis, focusing on biological and trace evidence. Students will learn safe DNA extraction techniques using a classroom-appropriate protocol, understand the principles underlying RFLP and STR DNA profiling, master fingerprint classification using the three primary pattern types, and develop skills in hair and fiber analysis. The unit culminates in an evidence analysis challenge that requires students to integrate all learned skills to solve a mock case.

Essential Questions

- How does biological evidence provide objective, scientific data in criminal investigations?
- What are the principles and limitations of DNA profiling in forensic science?
- How do fingerprint patterns form, and why are they considered unique identifiers?
- What role does trace evidence play in reconstructing events at a crime scene?
- How do forensic scientists maintain the integrity of evidence through proper collection and analysis?

Learning Objectives

1. Extract DNA from a biological sample using a classroom-safe protocol and explain the function of each step.

2. Compare and contrast RFLP and STR DNA profiling methods, including their advantages and limitations.

3. Classify fingerprints into three primary pattern types (arches, loops, whorls) and identify key minutiae points.

4. Analyze hair and fiber evidence microscopically to determine origin, characteristics, and evidentiary value.

5. Explain the function and significance of the CODIS database in forensic investigations.

6. Demonstrate proper evidence collection, documentation, and chain-of-custody procedures.

7. Synthesize multiple types of evidence to draw defensible, scientifically supported conclusions in a mock investigation.

NGSS Alignment

Standard	Description	Lessons
HS-LS1-1	Construct an explanation based on evidence for how the structure of DNA determines the structure of proteins	2, 3, 4, 5
HS-LS3-1	Ask questions to clarify relationships about the role of DNA and chromosomes in coding instructions for traits	2, 5, 11
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs	13, 14
SEP 4	Analyzing and Interpreting Data	4, 7, 8, 9, 10
SEP 6	Constructing Explanations and Designing Solutions	5, 12, 13, 14
CCC 1	Patterns — Observed patterns guide organization and classification	6, 7, 8
CCC 6	Structure and Function — Investigating how structure relates to function	2, 9, 10

Required Materials

- **DNA Extraction Lab:** Strawberries (fresh or frozen), resealable plastic bags, table salt, clear dish soap, cold water, chilled 91% isopropyl alcohol, coffee filters, test tubes or clear cups, wooden craft sticks, measuring spoons, safety goggles
- **Fingerprint Unit:** White index cards, black ink pads, magnifying glasses or loupes (10×), baby wipes, fingerprint classification reference sheets, clear tape
- **Hair & Fiber Analysis:** Microscope(s), microscope slides and coverslips, hair samples (human, dog, cat, synthetic), fiber samples (cotton, wool, nylon, polyester, silk), forceps, mounting medium or water
- **Evidence Challenge:** Case scenario packets, evidence bags (zip-lock), evidence labels, chain-of-custody forms, rulers, UV flashlights (optional), tweezers, collection containers
- **General:** Science notebooks or binders, colored pencils, rulers, calculators, access to reference materials or internet for research

Three-Week Pacing Guide

Week 1: DNA Evidence

Day	Lesson	Focus	Key Activity

Mon	1	Introduction to Forensic Science & Biological Evidence	Case study analysis, evidence sorting activity
Tue	2	DNA Structure & Function	DNA model building, base-pairing practice
Wed	3	DNA Extraction Lab – Day 1	Lab setup, extraction protocol, observation
Thu	4	DNA Extraction Lab – Day 2	Results analysis, lab report writing
Fri	5	RFLP & STR Profiling Basics	Gel electrophoresis simulation, profile matching

Week 2: Fingerprints & Trace Evidence

Day	Lesson	Focus	Key Activity
Mon	6	History & Science of Fingerprints	Historical case studies, basic principles
Tue	7	Fingerprint Classification	Classification guide, pattern identification practice
Wed	8	Fingerprint Analysis & Comparison	Minutiae identification, comparison exercises
Thu	9	Hair Analysis	Microscopic examination, structure identification
Fri	10	Fiber Analysis	Burn testing, microscopic fiber identification

Week 3: Integration & Culminating Activities

Day	Lesson	Focus	Key Activity
Mon	11	The CODIS Database	CODIS exploration, DNA profile matching activity
Tue	12	Trace Evidence Collection & Chain of Custody	Evidence collection simulation, documentation
Wed	13	Evidence Analysis Challenge – Day 1	Scene processing, evidence collection
Thu	14	Evidence Analysis Challenge – Day 2	Lab analysis, report writing
Fri	15	Unit Review & Assessment	Unit test, self-reflection

Assessment Overview

• **Formative Assessments:** Daily exit tickets, lab observations, class discussions, think-pair-share activities

- **DNA Extraction Lab Report:** Formal lab report following the scientific method (Lessons 3–4)
- **Fingerprint Classification Quiz:** Pattern identification and classification exercise (Lesson 8)
- **Trace Evidence Lab Sheet:** Hair and fiber identification under microscope (Lessons 9–10)
- **Evidence Analysis Challenge:** Comprehensive culminating activity with written report (Lessons 13–14)
- **Summative Unit Assessment:** Written exam covering all unit content (Lesson 15)

Grading Weight Suggestions

Category	Weight	Description
Formative / Daily Work	25%	Exit tickets, classwork, participation, warm-ups
Lab Reports	25%	DNA extraction report, trace evidence analysis sheets
Evidence Challenge	25%	Culminating project including written analysis report
Summative Assessment	25%	Unit test with multiple-choice, short-answer, and application questions

TEACHER TIP Print the Vocabulary Guide and Fingerprint Classification Guide at the start of the unit. Students can keep these in their forensic science binders as reference tools throughout all three weeks.

CAUTION The DNA extraction lab uses isopropyl alcohol (91%). Ensure proper ventilation, require safety goggles, and review your school's lab safety guidelines before the activity. Do not allow students to ingest any lab materials.

WEEK 1: DNA EVIDENCE

Week 1 introduces students to the foundational concepts of biological evidence in forensic science. Students will explore the structure of DNA, perform a classroom-safe DNA extraction, and learn the principles behind RFLP and STR profiling methods used in modern forensic laboratories.

LESSON 1: Introduction to Forensic Science & Biological Evidence

Learning Objectives

- Define forensic science and explain its role in the criminal justice system.
- Differentiate between biological, trace, and physical evidence with examples.
- State and apply Locard's Exchange Principle to forensic scenarios.

Materials

- Whiteboard and markers
- Handout: "Types of Evidence Sort" (teacher-created: 20 cards with various evidence examples)
- Science notebooks

Warm-Up (5 min)

Display the following question: *"If a crime is committed in a room with no cameras or witnesses, how can investigators prove what happened?"* Have students write a 3-sentence response in their notebooks. Share 2–3 responses with the class.

Direct Instruction (15 min)

Introduce **forensic science** as the application of scientific methods and processes to solving crimes. Explain that forensic scientists analyze evidence to establish facts that can be presented in a court of law.

Key Concept: Types of Evidence

- **Biological Evidence:** Evidence derived from living organisms (e.g., blood, saliva, semen, hair with root, skin cells). This is the most common source of DNA.
- **Trace Evidence:** Small quantities of physical evidence transferred during a crime (e.g., fibers, hair without root, soil, glass fragments, pollen).
- **Physical Evidence:** Any non-biological tangible object related to a crime (e.g., weapons, tools, documents, fingerprints).

Key Concept: Locard's Exchange Principle

Locard's Exchange Principle: "Every contact leaves a trace." Formulated by Dr. Edmond Locard, this principle states that a perpetrator will bring something into a crime scene and leave with something from it. This two-way transfer is the foundation of trace evidence analysis.

Guided Practice (15 min)

Distribute the "Types of Evidence Sort" cards. In pairs, students categorize the 20 evidence examples into Biological, Trace, or Physical evidence. Review as a class, discussing any items that could overlap (e.g., a hair with a follicle is biological, while a hair shaft without a root is trace).

Independent Practice (10 min)

Students write three original crime scenarios. Each scenario must feature one example of biological, one trace, and one physical evidence item. They must explain how Locard's Exchange Principle applies to the transfer of the trace evidence in their scenario.

Closure (5 min)

Exit Ticket: List one example of biological evidence and one of trace evidence. Why is biological evidence generally considered more powerful for individualizing a suspect?

TEACHER TIP Students often confuse trace and physical evidence. Emphasize that trace evidence is defined by its microscopic or minuscule quantity, whereas physical evidence is a broader category. Trace evidence is a subset of physical evidence, but we separate it in forensics due to the specialized microscopic techniques required.

LESSON 2: DNA Structure & Function

Learning Objectives

- Describe the structure of DNA, including the double helix, nucleotides, and base pairing.
- Explain the function of DNA in storing genetic information.
- Identify why DNA is considered the 'gold standard' of biological evidence.

Materials

- Colored paper (4 colors for base pairs), scissors, tape
- DNA structure diagram (for projection)
- Science notebooks

Warm-Up (5 min)

Display: *"What do you know about DNA? Write three facts. If you are unsure, write three questions you have about it."*

Direct Instruction (20 min)

Explain that DNA (Deoxyribonucleic Acid) is the molecule of heredity, found in the nucleus of almost every cell in the human body. Its unique sequence in every individual (except identical twins) makes it the most powerful tool for identification in forensic science.

DNA Structure Components:

- **Nucleotide:** The basic building block of DNA, composed of three parts:
  - A phosphate group
  - A deoxyribose sugar
  - A nitrogenous base
- **Base Pairing Rules:** Adenine (A) always pairs with Thymine (T), and Cytosine (C) always pairs with Guanine (G). These are held together by hydrogen bonds.
- **Double Helix:** Two strands of nucleotides running in opposite directions (antiparallel), twisting into a spiral shape.

Forensic Relevance: While 99.9% of human DNA is identical, the remaining 0.1% contains variable regions (polymorphisms) that differ greatly between individuals. Forensic DNA profiling targets these variable regions to generate a DNA profile that is virtually unique to a single person.

Guided Practice (15 min)

LESSON 8: Fingerprint Analysis & Comparison

Learning Objectives

• Identify and label ridge characteristics (minutiae) in a fingerprint.
• Apply the ACE-V methodology to compare a latent print to a known exemplar.
• Determine whether a latent print can be individualized to a suspect.

Materials

- Fingerprint comparison worksheets (enlarged latent and known prints)
- Magnifying glasses or loupes
- Colored pencils or fine-tip markers

Warm-Up (5 min)

> Display a zoomed-in image of two fingerprints side-by-side. Ask: *"Are these the same fingerprint? What specific details would you look at to make your decision?"*

Direct Instruction (15 min)

Explain that while pattern classification (arch, loop, whorl) narrows down a search, it cannot individualize a print. Individualization relies on **minutiae** (ridge characteristics).

Common Minutiae Types:

Minutiae Type	Description
Ridge Ending	A ridge that stops abruptly.
Bifurcation	A single ridge that splits into two separate ridges.
Dot (Island)	A very short ridge that looks like a single dot.
Short Ridge (Island)	A ridge that begins, travels a short distance, and ends.
Enclosure (Eye)	A ridge that splits and rejoins, creating an enclosed space.
Bridge	A short ridge connecting two parallel ridges.

The ACE-V Methodology:

Explain the standard procedure used by forensic examiners worldwide:

1. Analysis: Assess the latent print's quality, clarity, and usable minutiae. Determine if there is enough detail to make a comparison.

2. Comparison: Compare the latent print side-by-side with a known exemplar, looking for agreement in minutiae types and spatial relationships.

3. Evaluation: Reach a conclusion: Individualization (match), Exclusion (no match), or Inconclusive (insufficient detail).

4. Verification: An independent second examiner reviews the conclusion to ensure accuracy and prevent bias.

Guided Practice (20 min)

Students receive a comparison worksheet with one latent print and one known suspect print. They must use colored markers to circle and label at least 8 matching minutiae (e.g., circle a bifurcation on both prints in red, a ridge ending in blue) and map the spatial relationship. Emphasize that the minutiae must match in type, location, and relative position.

Closure (5 min)

Exit Ticket: What is the difference between classifying a fingerprint (arch/loop/whorl) and individualizing a fingerprint? Why is ACE-V necessary?

DNA EXTRACTION LAB PROTOCOL

This classroom-safe DNA extraction protocol uses common household materials to extract visible strands of DNA from strawberries. Strawberries are ideal for this lab because they are octoploid (8 copies of each chromosome), yielding a large, easily visible quantity of DNA.

CAUTION This lab uses 91% isopropyl alcohol, which is flammable and an eye irritant. Safety goggles must be worn at all times. Do not ingest any lab materials. Ensure adequate ventilation. Dispose of waste in designated containers.

Materials (Per Group of 2–3 Students)

- 1–2 fresh or frozen strawberries (thawed if frozen)
- 1 resealable plastic sandwich bag
- 10 mL DNA Extraction Buffer (see preparation below)
- 50 mL chilled 91% isopropyl alcohol (place in freezer overnight)
- 1 coffee filter
- 1 clear plastic cup or beaker
- 1 clear test tube or narrow glass
- 1 wooden craft stick (for spooling)
- Safety goggles

Extraction Buffer Preparation (Teacher/Student)

Buffer Recipe

Mix the following to create the DNA Extraction Buffer:
- 10 mL clear dish soap (contains surfactants to dissolve lipids)
- 1 g table salt (sodium chloride to neutralize charges and precipitate proteins)
- 90 mL distilled water

Stir gently to avoid creating excessive bubbles.

Procedure

1. Prepare the Sample: Place 1–2 strawberries into the resealable plastic bag. Seal the bag, removing as much air as possible.

2. Mechanical Breakdown: Using your fingers, thoroughly smash the strawberries inside the bag for 2–3 minutes until no large chunks remain. *(This breaks the rigid plant cell walls.)*

3. Chemical Lysis: Add 10 mL of the DNA Extraction Buffer to the bag. Reseal the bag (removing air) and gently mix and smash for another 2 minutes. Avoid creating too many bubbles. *(The soap dissolves the cell and nuclear membranes; the salt separates proteins from the DNA.)*

4. Filtration: Place a coffee filter over the opening of a clear cup. Secure it with a rubber band if necessary. Pour the strawberry mixture into the filter. Allow the liquid to drip through into the cup. Do not squeeze the filter. *(This separates the dissolved DNA from the cellular debris.)*

5. Precipitation: While tilting the cup or test tube at a 45-degree angle, slowly pour 50 mL of the **chilled** isopropyl alcohol down the side of the container so that it forms a layer on top of the strawberry liquid. **Do not mix or stir.**

6. Observation: Wait 1–2 minutes. You will see a stringy, white, mucus-like substance rise into the alcohol layer. This is the extracted DNA! *(DNA is insoluble in cold alcohol, causing it to precipitate out of solution.)*

7. Spooling: Use the wooden craft stick to gently twirl and lift the DNA out of the liquid. Place the DNA on a paper towel to observe.

Data & Observations

Step	Observation (What did you see/hear/feel?)
2. Mashing the strawberry	
3. Adding extraction buffer	
4. Filtering the mixture	
5. Adding cold alcohol	
6. DNA Precipitation	
7. Spooling the DNA	

Analysis Questions

Answer the following questions in complete sentences in your lab notebook.

1. What was the purpose of the dish soap in the extraction buffer? What cellular structure does it target?

2. What was the purpose of the table salt? How does it interact with the histone proteins?

3. Why was it necessary to chill the isopropyl alcohol? What would happen if the alcohol was room temperature?

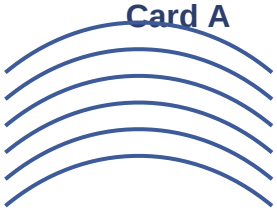
4. Why are strawberries used instead of human cheek cells in this classroom lab? (Hint: Consider ploidy).

5. If you performed this extraction on human cells, which step would need to be modified and why? (Hint: Consider the cell wall).

FINGERPRINT PRACTICE CARDS

Use these practice cards to test your ability to classify fingerprints and identify key landmarks. The red dots represent the approximate location of deltas. For each card, identify the primary pattern type, the sub-type, and the number of deltas.

Card A

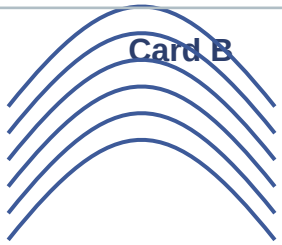


Pattern Type: _____

Sub-type: _____

Number of Deltas: _____

Card B

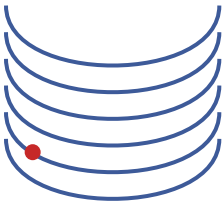


Pattern Type: _____

Sub-type: _____

Number of Deltas: _____

Card C



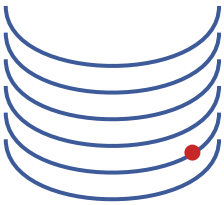
Pattern Type: _____

Sub-type: _____

Number of Deltas: _____

Assume this is from a RIGHT hand.

Card D



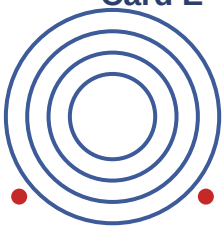
Pattern Type: _____

Sub-type: _____

Number of Deltas: _____

Assume this is from a RIGHT hand.

Card E

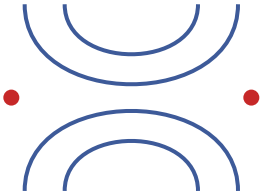


Pattern Type: _____

Sub-type: _____

Number of Deltas: _____

Card F



Pattern Type: _____

Sub-type: _____

Number of Deltas: _____

Practice Cards Answer Key

Card	Pattern Type	Sub-type	Deltas
A	Arch	Plain Arch	0
B	Arch	Tented Arch	0
C	Loop	Ulnar Loop	1

FORENSICS VOCABULARY GUIDE

Mastering the terminology is essential for any forensic scientist. Use this guide as a reference throughout the unit. Terms are organized by topic.

Term	Definition
Allele	One of two or more alternative forms of a gene at a specific locus on a chromosome.
Amelogenin	A gene used in DNA profiling to determine the biological sex of the sample contributor (XX or XY).
CODIS	Combined DNA Index System; the FBI's national database of DNA profiles from convicted offenders, arrestees, and forensic evidence.
DNA	Deoxyribonucleic acid; the molecule that carries the genetic instructions for life, found in the nucleus of cells.
DNase	An enzyme that degrades DNA. Cold alcohol in extraction labs slows these enzymes down.
Gel Electrophoresis	A technique used to separate DNA fragments by size using an electrical current through a gel matrix.
LDIS / SDIS / NDIS	Local, State, and National DNA Index Systems—the three hierarchical tiers of the CODIS database.
Nucleotide	The basic building block of DNA, consisting of a phosphate group, a deoxyribose sugar, and a nitrogenous base.
PCR	Polymerase Chain Reaction; a technique used to amplify (make millions of copies of) specific regions of DNA from a tiny sample.
Polymorphism	A region of DNA that varies greatly among individuals, making it useful for identification.
RFLP	Restriction Fragment Length Polymorphism; an older DNA profiling technique that cuts DNA with restriction enzymes and separates fragments by size.
STR	Short Tandem Repeat; the modern standard for DNA profiling that counts the number of repeated base sequences at specific loci.
Arch	A fingerprint pattern where ridges enter one side, rise in the center, and exit the opposite side. Has 0 deltas.
Bifurcation	A minutiae point where a single ridge splits or forks into two separate ridges.

3. A forensic scientist extracts DNA from a crime scene, but the sample is very small. Explain the process they will use to generate enough DNA for profiling, and name the technique.

4. Explain how the medullary index is calculated and what threshold values distinguish human hair from animal hair.

5. Why is the chain of custody considered critical in forensic science? What could happen if it is broken?

Part 3: Practical Application (10 points each)

1. A trace evidence analyst measures a hair shaft under a microscope. The shaft diameter is 80 μm, and the medulla diameter is 24 μm. Calculate the medullary index. Show your math. Based on your calculation, is this hair likely human or animal? Justify your answer.

2. A latent fingerprint is recovered from a crime scene. The ridges enter from one side, rise to a sharp, defined point in the center (resembling a tent pole), and exit the opposite side. Classify this fingerprint by pattern type, sub-type, and number of deltas.

5. The chain of custody is critical because it proves the integrity of the evidence. It documents who handled the evidence, when, and why. If the chain is broken, the defense can argue the evidence was tampered with, contaminated, or planted, which can result in the evidence being deemed inadmissible in court.

Part 3: Practical Application

1. MI = Diameter of Medulla ÷ Diameter of Hair Shaft
MI = 24 μm ÷ 80 μm = 0.30
Conclusion: The hair is likely **human**, because the MI (0.30) is less than 0.33. Animal hair typically has an MI greater than 0.50.

2. Pattern Type: **Arch**. Sub-type: **Tented Arch**. Number of Deltas: **0**. (The sharp upthrust differentiates it from a plain arch, but it still lacks a delta and core).