Projectile and Gunshot Residues
Locard’s Principle

“There is no such thing as a clean contact between two objects. When two bodies or objects come into contact they mutually contaminate each other with minute fragments of material”

Dr Edmund Locard, *Revue Internationale de Criminalistiques* 1 (1929) 176
Early forensic ballistics

1794 Edward Culshaw shot in the head at Prescot, Lancs.

Surgeon examines wound and finds paper wad used to pack shot

Paper is extract of a street ballad

Remainder of ballad sheet found in the coat pocket of 18 year old suspect, John Toms.

23 March 1794 Toms sentenced to death at Lancaster Assizes
Early forensic ballistics

1860 Policeman killed with double-barrelled pistol.

Paper wad in wound from *The Times* 27 March 1854

Suspect Richardson found to have matching page fragment in the unfired barrel of his pistol

Richardson convicted and hanged
Early forensic ballistics

1891 France - Charles Guesner shot whilst asleep with his wife

Paper wad in wound from *Lorraine Almanach*

Suspect Bivert had courted Madame Guesner prior to her marriage

Copy of *Lorraine Almanach* with relevant page missing found in Bivert’s room

Bivert sentenced to 20 year’s hard labour
Small arms round with bullet

- Primer
- Percussion cap
- Anvil
- Cartridge case
- Flash holes
- Propellant
- Gilding metal jacket
- Pb/Sb core
Shotgun cartridge

- Primer
- Brass end cap
- Rolled paper or plastic tube
- Percussion cap
- Propellant
- Shot
- Cardboard disk
Firing a gun

On discharge, propellant explodes, projectile forced down barrel.

Barrel rifled to make bullet spin, so trajectory is stabilized.

Bullet slightly larger than barrel, lands or rifling on inside of barrel creates characteristic scratches on bullet.

Process of rifling chips fragments off bullet casing & lead. These are expelled with propellant residues on firing.
Matching bullets to guns

1889 Professor Alexander Lacassagne secures a conviction by noting that murder bullet had seven grooves, the same as one fired from suspect’s gun.

1912 Professor Victor Balthazard identifies 85 similarities between the bullet which killed Guillotin and one fired by the weapon of the suspect, Houssard.

1912 Robert Churchill makes wax impression of lands and grooves inside gun barrel for comparison with the 2 bullets which killed Inspector Albert Walls. George McKay convicted and hanged.
Propellant residues

On discharge, powder residues from propellant and metal fragments from bullet lead and casing are deposited on the hand(s) of person firing the weapon.

If victim close enough, residues also deposited on victim.

Rifle held at the shoulder leaves residues on the (generally right) cheek.
Analyses for gunshot residues

Used, e.g.,

- to establish death by suicide (i.e., victim was holding gun)
- to identify the person who discharged a gun
- to establish that bullet fragments belong to a particular bullet
- to establish that several bullets are from the same gun or box of bullets
- to establish which bullet came from which gun
Some common explosives

- nitroglycerin
- trinitrotoluene
- cyclotrimethylenetrinitramine (RDX)
- Pentacrythritoltetranitrate (PETN)
- Cellulose nitrate (nitrocellulose gun cotton)
Propellants ("gunpowder"):

**Black powder =**
\[ 15\text{C}: 75\text{KNO}_3 :10\text{S} \]

**Smokeless powders:**
- Single base = nitrocellulose
- Double base = nitrocellulose & nitroglycerine

**Primer composition:**

- Explosive: e.g., lead styphnate = lead trinitroresorcinate, (mercury fulminate)
- Oxidiser: e.g., barium nitrate, \( \text{BaNO}_3 \)
- Fuel: antimony sulfide, \( \text{Sb}_2\text{S}_3 \)

(fricitonators, sensitizers, binders)
Primer fuel

\[ \text{Sb}_2\text{S}_3 \text{ antimony sulfide} \]

Primer explosive

Lead styphnate ($\alpha$-form) partial structure

Generic strategies for the detection of nitrate (and nitrite) ions
Bulk chemical assay for nitrates

“The method of testing hands of the suspect for nitrates derived from the blow back of the ignition of a cartridge fired from a weapon was developed many years ago. The method has been the subject of considerable work in the United States. It consists of a casting in paraffin wax of the forefinger, thumb, and other parts of the hand subject to blow back and the treatment of the cast with a solution of diphenylamine in sulfuric acid. The spots of nitrate are shown as deep blue spots. In practice, I have found this test quite unreliable since it is common to obtain positives when no gun has been used and negatives when a gun has been used. In these circumstances I do not consider the test of forensic value.”

Inorganic spot test for nitrate

\[ \text{H}^+ + \text{NO}_3^- \rightarrow \text{HNO}_3 \]

colourless

[Chemical structure of nitroblue tetrazolium (NBT)]

blue
The production of shot

Molten lead / antimony / barium / etc. mixture dropped down shot tower. As it falls, molten lead solidifies into small spheres.

San Francisco Shot Tower

Baltimore Shot Tower
Bullet Leads

generally either:

*soft lead* (> 99% Pb; 1 ppm < [Sb] < 1500 ppm)

or

*hard lead* (95 - 99% Pb; 0.4% < [Sb] < 4%)

other elements include Ag, Cu, As, Sn, Ba

Metal Jacket

Required under 1922 Geneva Convention (so bullets will pass through body if no organs are struck). Also decreases fouling of barrel interior by soft lead residues.

generally

95% Cu / 5% Zn or 90% Cu / 10% Zn or 87% Cu / 13% Zn
Spot test for lead

Test area is swabbed with a solution of sodium rhodizonate, after an acid wash to extract insoluble lead. If lead is present, the fine particles of lead turn reddish purple.
Murder of Oscar Bonavena

May 22 1974
Argentine heavyweight boxer, Oscar Bonavena, shot and killed at the Mustang Ranch in Nevada, “the world’s most famous legal brothel”.

Bonavena hit by a single bullet, which passed through his body and was never recovered.
Fragments of bullet and casing collected from the wound track.

Bonavena v. Ali Dec 7 1970
Murder of Oscar Bonavena

Two men, one armed with Remington 30.06 rifle, the other with AR-15 rifle, seen firing at Bonavena.

Bullet from wound track:
$4.85 \pm 0.29\% \text{ Sb}, 44 \pm 6 \text{ ppm Ag}, 780 \pm 120 \text{ ppm Cu}$

Bullets from 30.06 rifle:
$4.72 \ 0.15\% \text{ Sb}, 38 \pm 4 \text{ ppm Ag}, 470 \pm 300 \text{ ppm Cu}$

Bullets from AR-15 rifle:
$0.75 \pm 0.03\% \text{ Sb}, 71 \pm 2 \text{ ppm Ag}, 300 \pm 40 \text{ ppm Cu}$
Murder of Oscar Bonavena

Metal jacket fragments in wound track:
95% Cu / 5% Zn

Metal jacket of 30.06 rifle bullet:
95% Cu / 5% Zn

Metal jacket of AR-15 rifle bullet:
90% Cu / 10% Zn

Conclusion: suspect with 30.06 rifle fired the fatal shot
The Assassination of President Kennedy

*Dallas November 22 1963*
Motorcade route
President Kennedy  Governor Connally

Direction of car

Mrs Kennedy  Mrs Connally
The bullets

3 shots fired:

1. apparently missed, never found
2. hit Kennedy in back, exited from throat, hit Connally in back, glanced off a rib, exited from chest, shattered right wrist (received a dent in nose and deposited several fragments CE 842), embedded in left thigh - fell out onto stretcher (CE 399 “stretcher (or magic) bullet”)
3. fatal shot. Hit Kennedy in back of head (leaving fragments in brain CE 843), exited from right front of head, bullet fracturing into several small pieces (CE 567, CE 840, CE 843)
Bullet casting

Lead cast into ingots, then extruded to form bullets
## Neutron Activation Analysis results

<table>
<thead>
<tr>
<th>Sample</th>
<th>[Ag] (ppm)</th>
<th>[Sb] (ppm)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE399</td>
<td>8.8 ± 0.5</td>
<td>833 ± 9</td>
<td>Connally stretcher bullet</td>
</tr>
<tr>
<td>CE 842</td>
<td>9.8 ± 0.5</td>
<td>797 ± 7</td>
<td>Fragments from Connally’s wrist</td>
</tr>
<tr>
<td>CE 567</td>
<td>8.1 ± 0.6</td>
<td>602 ± 4</td>
<td>Large fragment found in car</td>
</tr>
<tr>
<td>CE 843</td>
<td>7.9 ± 0.3</td>
<td>621 ± 4</td>
<td>Fragments from President Kennedy’s brain</td>
</tr>
<tr>
<td>CE 840</td>
<td>8.2 ± 0.4</td>
<td>642 ± 6</td>
<td>Small fragments found in car</td>
</tr>
</tbody>
</table>
Care in forensic chemistry

“.. nearly nine hours after the assassination, the police took paraffin casts of Oswald’s hands and his right cheek. The theory of the test is that gunpowder residue will react with the paraffin and turn blue on the cast. Oswald’s hands proved positive; his cheek, however, was negative....”

Gerald Posner (1993) Case Closed Lee Harvey Oswald and the Assassination of JFK
Care in forensic chemistry

_the conduct of forensic examinations_

“...All of the analytical measurements conducted by the Dallas police (inconclusive dermal nitrate tests run on paraffin casts taken of Oswald’s hands and his right cheek soon after he was apprehended) and by the FBI Laboratory shed very little light on the subject. The FBI took the Oswald paraffin casts to the Oak Ridge National Laboratory and analyzed them by neutron activation analysis (NAA) for the possible presence of primer residue (barium and antimony) still there even after the Dallas dermal nitrate tests. This effort was thwarted by the fact that the casts were badly contaminated, essentially as much Ba and Sb being found on the outside surfaces of the casts as on the inside surfaces - which had been in contact with Oswald’s skin....”

V P Guinn, _Anal. Chem._, 51 (1979) 484A
Care in forensic chemistry
Wednesday May 15 1996

“Forensic scientists discovered contamination while cleaning a centrifuge machine, which has been a crucial piece of equipment in the analysis in all bomb cases since 1989. Traces of the explosive RDX, a substance found in Semtex, were discovered on a rubber bung. Although scientists stressed that the contamination was minute - 16 times smaller than a grain of sugar - Home Office officials admitted that the amount was significant for the kind of quantities involved in analysing explosives. The Sevenoaks laboratory has tested over 500 separate samples from bomb scenes and suspects since 1989.”

Fri 25 July 1997

“The British Home Secretary has apologised to the Birmingham Six for the miscarriage of justice they suffered. The men have complained for many years that no official has ever offered them an apology for their false imprisonment.”
Other techniques for detecting cartridge discharge residue (CDR), firearms discharge residue (FDR) or gunshot residue (GSR)

Flameless atomic absorption spectroscopy

Molecular luminescence

Electron spin resonance spectroscopy

X-ray analysis

Electroanalytical methods

Scanning electron microscopy/energy dispersive X-ray analysis (SEM/EDX)

concentrate predominantly on inorganic constituents