Ballistics

26th august 2020

bal·lis·tics

/bəˈlistiks/

noun

the science of projectiles and firearms.

- the study of the effects of being fired on a bullet, cartridge, or gun.

https://www.google.com/search?q=ballistics&oq=ballistics&aqs=chrome.0.69i59l2j0l3j69i60.2903j0j4&sourceid=chrome&ie=UTF-8

- **พระราชบัญญัติอาวุธปืน เครื่องกระสุนปืน วัตถุระเบิด ดอกไม้เพลิง และสิ่งเทียมอาวุธปืน พ.ศ.2490**

มีเครื่องกระสุนไว้ในครอบครองโดยไม่ได้รับอนุญาต(ไม่ถูกขนาดกับปืนที่มีใบอนุญาต) อัตราโทษ ต้องระวางโทษจำคุกไม่เกิน 10 ปี หรือปรับไม่เกิน 20,000 บาท หรือทั้งจำทั้งปรับ การประกันตัว(เงินสด) ประมาณ 20,000-50,000 บาท

http://wanlop-style.blogspot.com/p/blog-page_23.html

Introduction to firearms and their ammunition

- General firearms used to commit the crimes
  - Handguns, rifles, shotguns

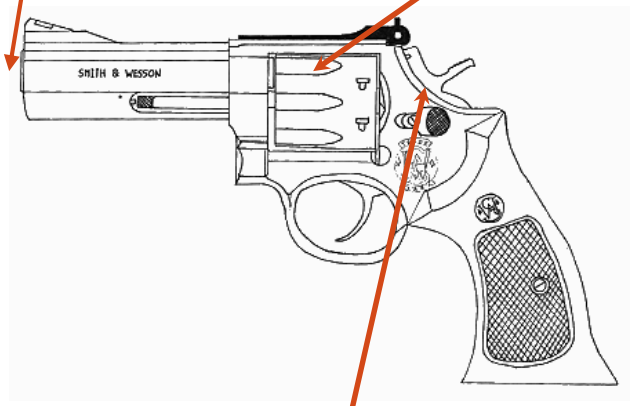
- Accompanying ammunition for firearms commonly contain
  - Cartridge case, a primer, propellant and a projectile (i.e. bullet) or projectiles (i.e. shot)

Handguns

- A firearm designed to be held in and discharged from one hand, whether single-shot, self-loading or revolver in design

https://en.wikipedia.org/wiki/Handgun

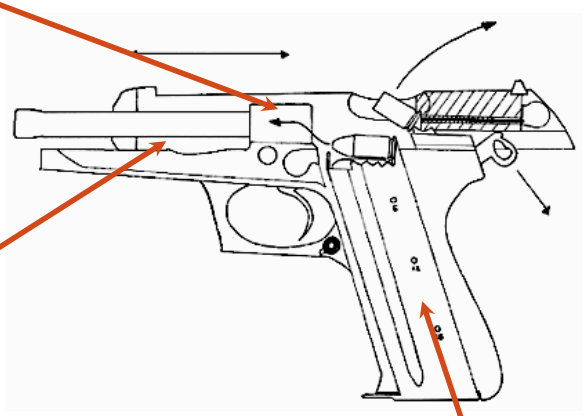
Anatomy of the Gun



Muzzle

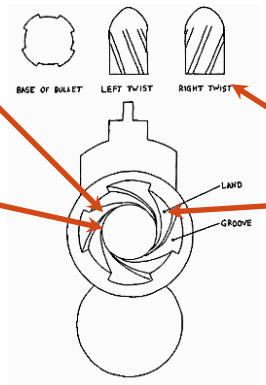
Chamber

Hammer



Barrel

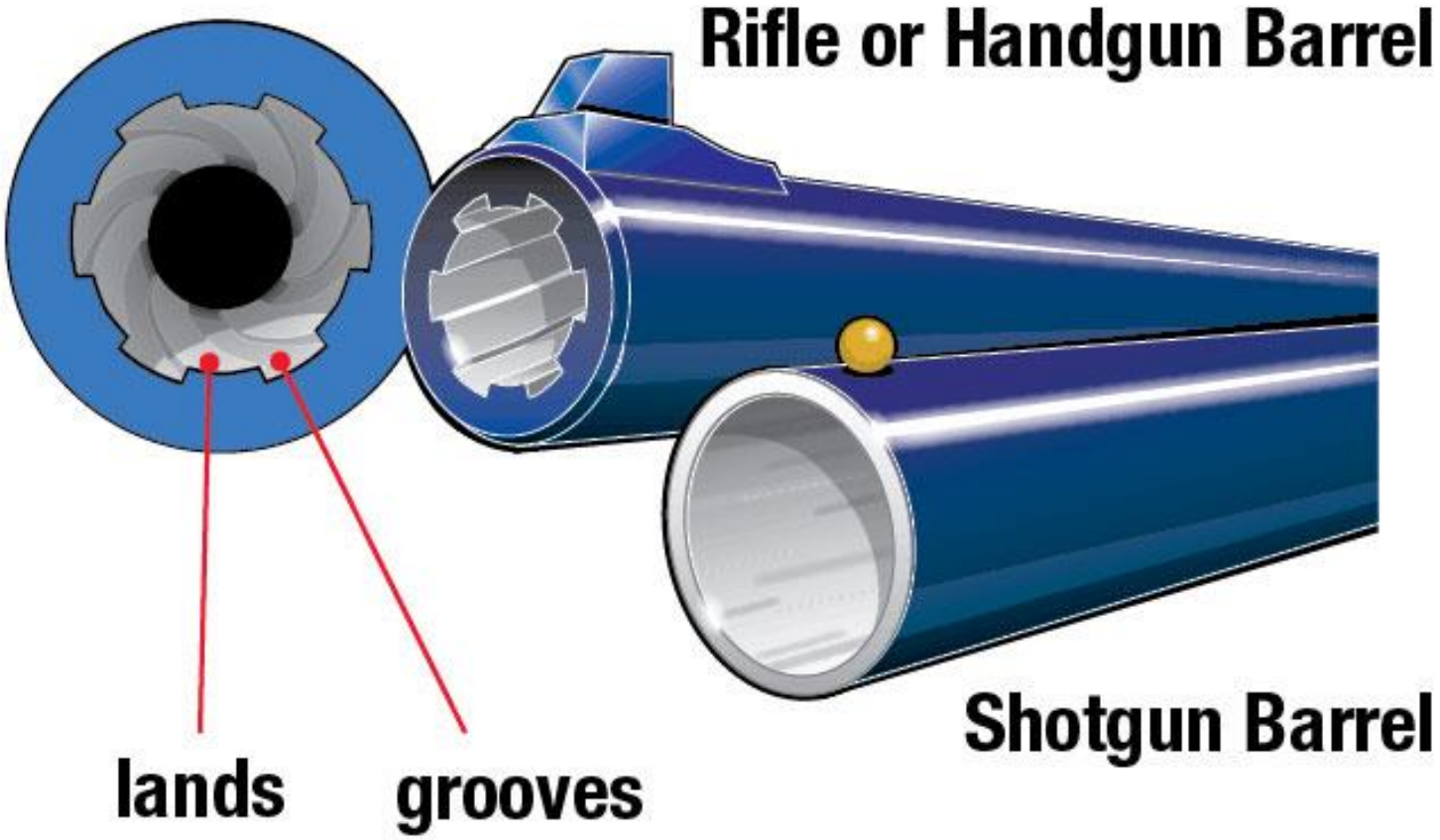
Magazine (Clip)



Bore

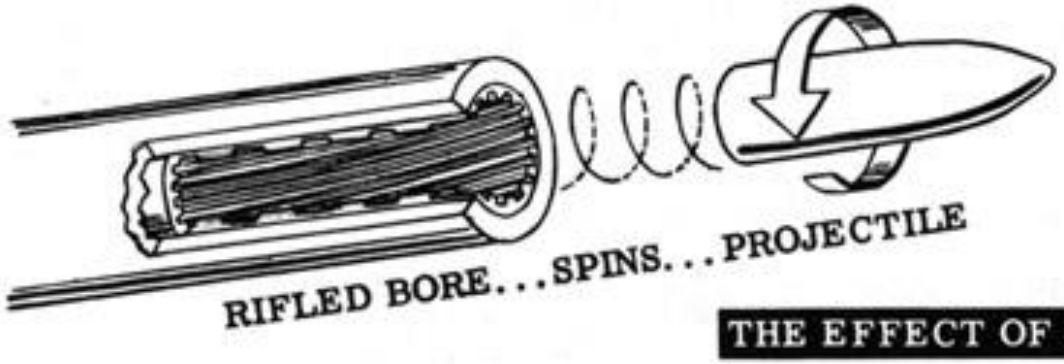
Caliber

Rifling



lands: The ridges of metal between the grooves in a rifled bore;
grooves: The spiral cuts in a rifled bore

https://www.hunter-ed.com/pennsylvania/handbook/book.html?page=14



THE EFFECT OF A RIFLE BORE

- Rifling is the term given to the spiral grooves cut into the bore of the barrel which impart a stabilizing to the bullet.
- This spin keeps the bullet travelling in a point-first direction and lessens any tendency for it to depart from its straight line of flight.
- **Angular momentum is the amount of rotation in a body and characterizes an objects resistance to change in rotation similar to how a body moving laterally has linear momentum, a spinning body has angular momentum.**
- **The quantity of rotation of a body is the product of its moment of inertia and angular velocity.**

https://maritime.org/doc/firecontrol/partb.htm

Right or left rifling

- **Stirations:** Tiny, microscopic scratches on the surface of the bullet, usually located inside the rifling impressions. ***No two firearms will produce exactly the same pattern of striations.***

https://www.slideshare.net/joelmotuk/csi-training-toolmarks-and

Rifles

- A firearm with a rifle barrel, which fires bullets and that is designed to discharged while held in both hands, in most cases, while held against a shoulder.

Modern hunting rifle

Shotguns

- A firearm, the barrel or barrels of which have a smooth (i.e. not rifled) interior and which is designed to fire shot, and to be discharged while held in both hands and, in most cases, while held against shoulder.

A U.S. Marine fires a Benelli M4 shotgun during training

http://en.wikipedia.org/wiki/shortguns

ปืนไทยประดิษฐ์ ลูกซองสั้น

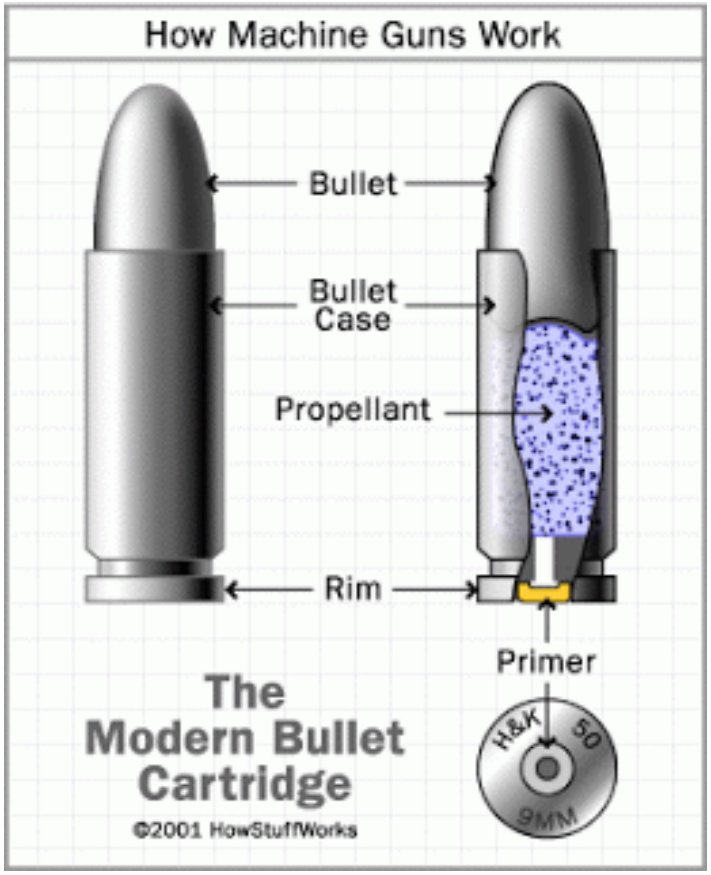
www.thairath.co.th/news/local/central/1121197

ปืนปากกาสำหรับกระสุนขนาด .22

https://www.thairath.co.th/content/649681

Cartridge (firearm)

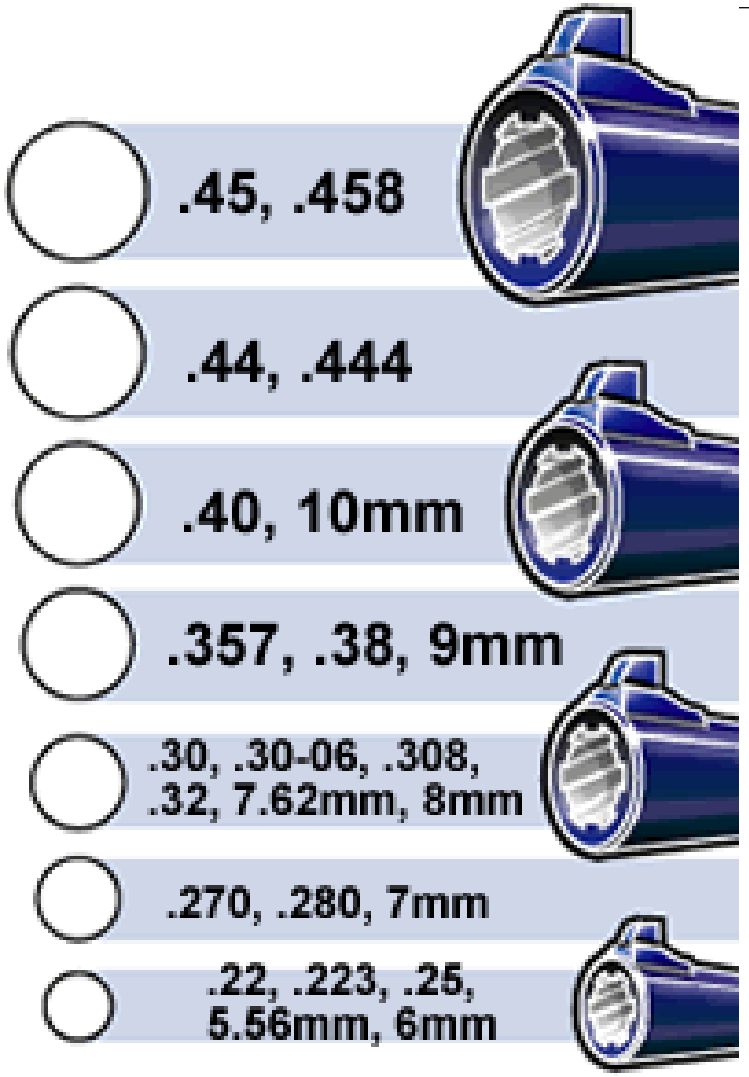
- Cartridge is composed of (1) bullet, (2) bullet case or cartridge case, (3) gun powder or propellant and (4) primer.
- Bullet designs have to solve two primary problems.
  - They must first form a **seal** with the gun's bore.
  - The bullet must also **engage the rifling** without damaging the gun's bore. Bullets must have a surface which will form this seal without causing excessive friction.



http://airsoftbobby.blogspot.com/2009/03/info-how-ballistic-works.html

Bullet caliber

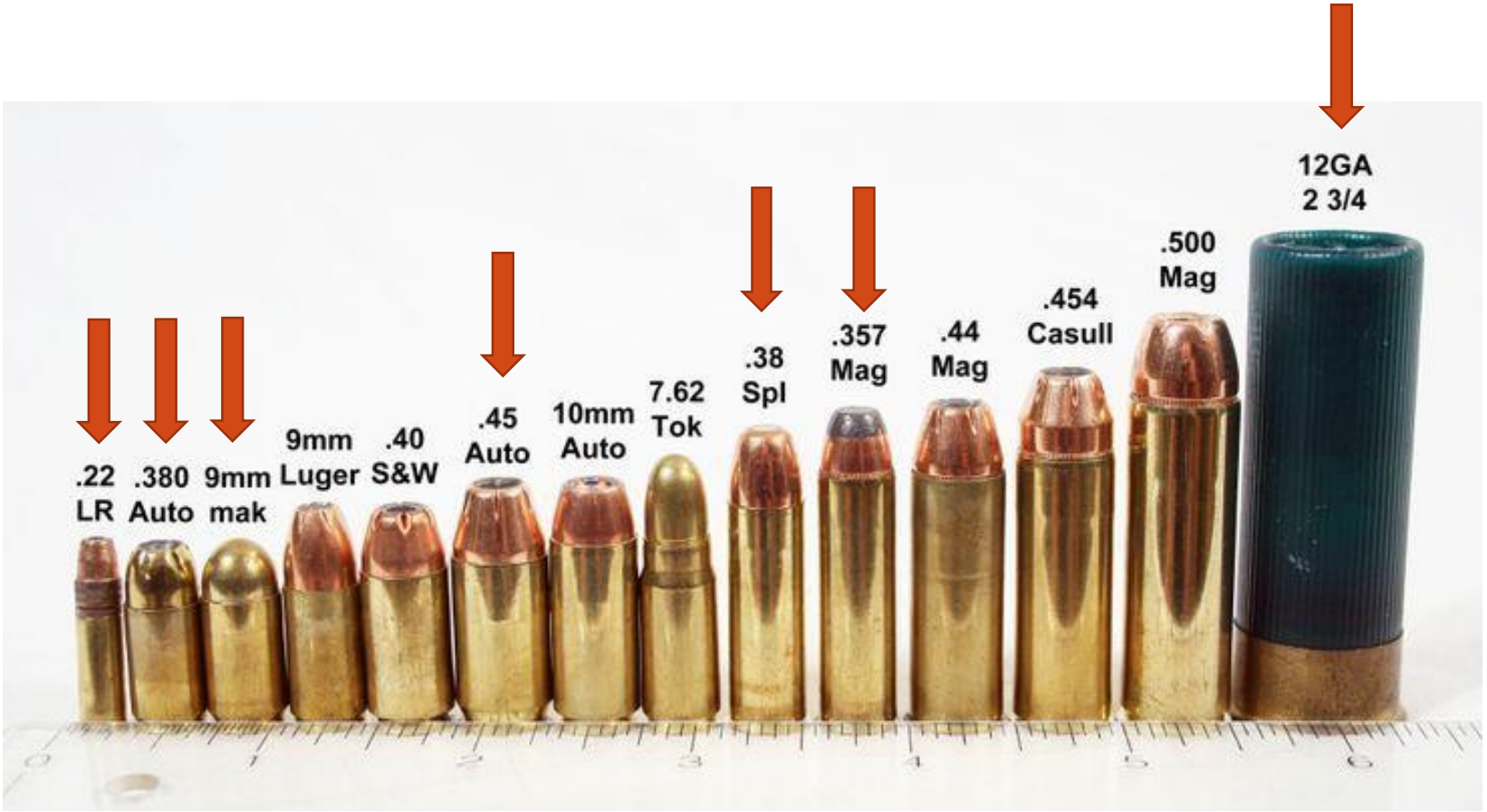
- The bore is the diameter of the inside of the gun's barrel.
- Caliber describes the size of the cartridge designed for a specific bore.
- The diameter of the barrel (the bore) is basically the same as the caliber the gun uses.



The caliber (size of bullet, left) has to fit the bore (right).

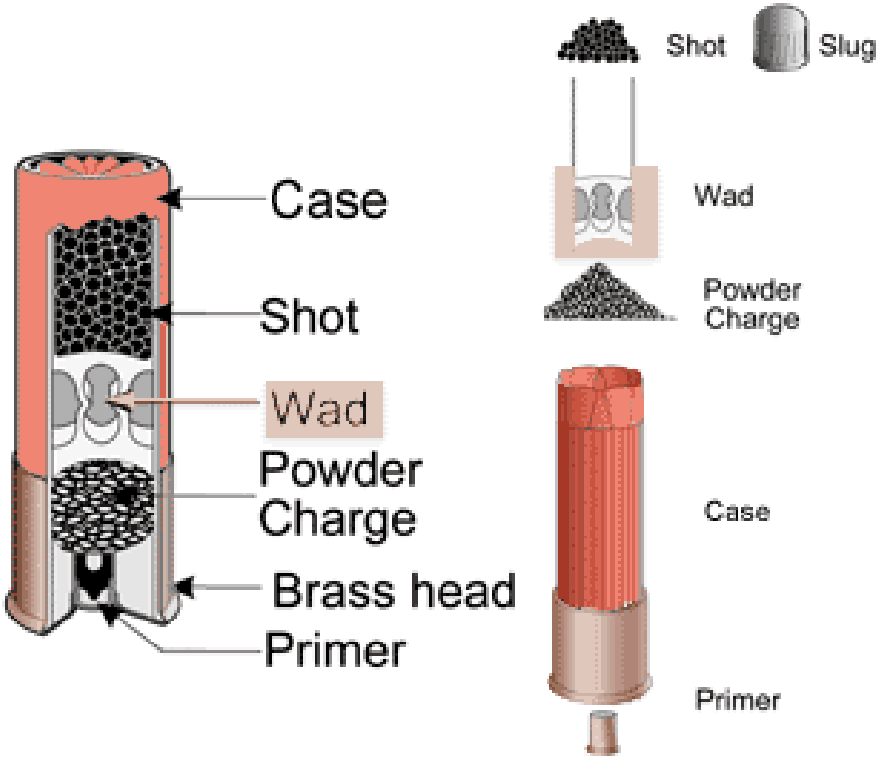
http://www.leelofland.com/wordpress/?p=734

Caliber is expressed in terms of inches or millimeters



https://www.pinterest.com/pin/1428492379828380 3/

What inside a shotgun cartridge.



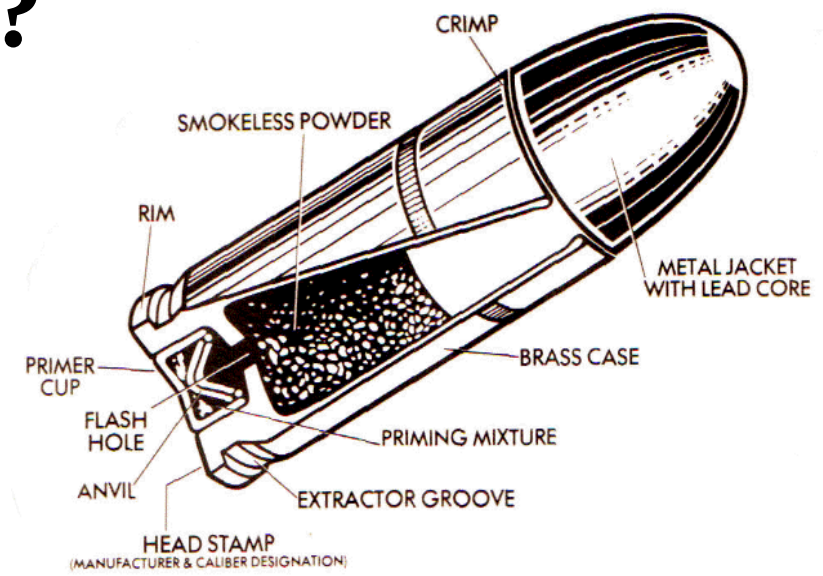
In addition to a case, primer, and powder, there is also a wad of plastic or fiber separating the shot from the powder. Instead of a bullet, shells are filled with “shot” – small, round pellets usually made of lead or steel.

Physics and ballistics

- The physics of projectiles in motion is called ″ballistics.
- The physics of ballistics related to firearms is divided into three separate fields:
- **Internal Ballistics** - The study of what happens inside of the firearm.
- **External Ballistics** - The study of what happens during the bullet's flight.
- **Terminal Ballistics** - The study of what happens when the projectile strikes the target.

Internal ballistic : What happens when the trigger is pulled?

1. Primer fired,
2. Intense flame passing through the flash hole,
3. Powder burns, creating large gas expansion
4. Generated huge pressure pushing bullet
5. The pressure also causing the gun recoil.

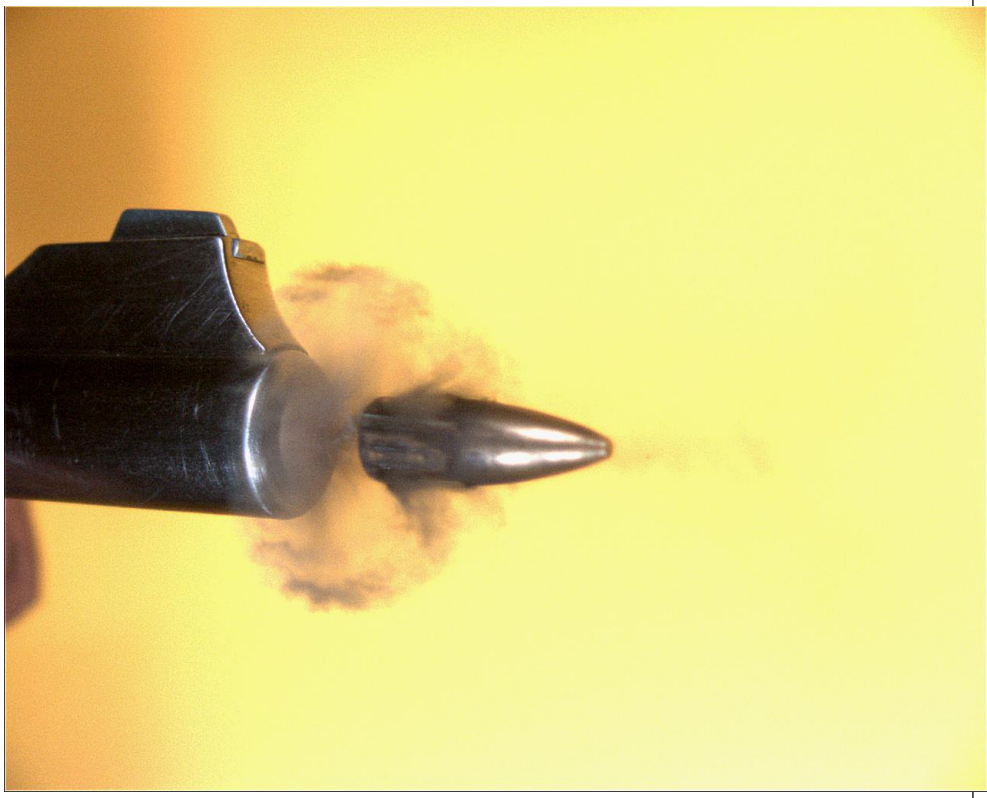


All primer explosives currently manufactured in the U.S. use chemical ingredients that are non-mercuric and noncorrosive. The compounds that are used vary: **lead styphnate, barium nitrate, and antimony sulfide** are most commonly used.

https://forum.thefreedictionary.com/poststt101951_Samuel-Colt--1814-.aspx

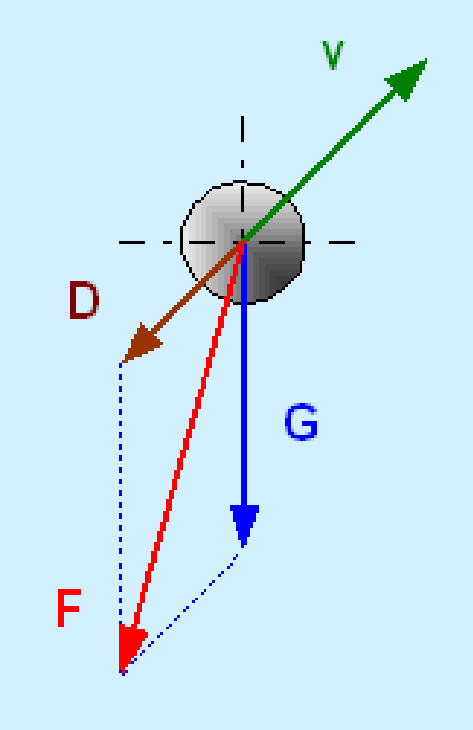
External Ballistics

- The study of projectile behavior after discharge from the firearm but prior to impact with the target.
- Two main factors considered to affect the bullet trajectory are **gravity and air resistance.**



A bullet is being fired from a revolver.

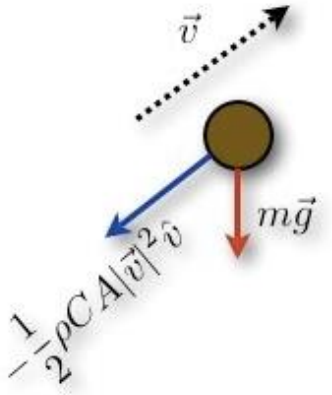
Free body diagram of an object in flight



- Basic forces acting on an object on flights are the gravity force (**G**) and drag force (**D**).
- The drag **D** is in exactly opposite direction of the velocity **v**.
- The resultant force **F** resists the motion of the object in flight.

http://www.codeproject.com/Articles/19107/Flight-of-a-projectile

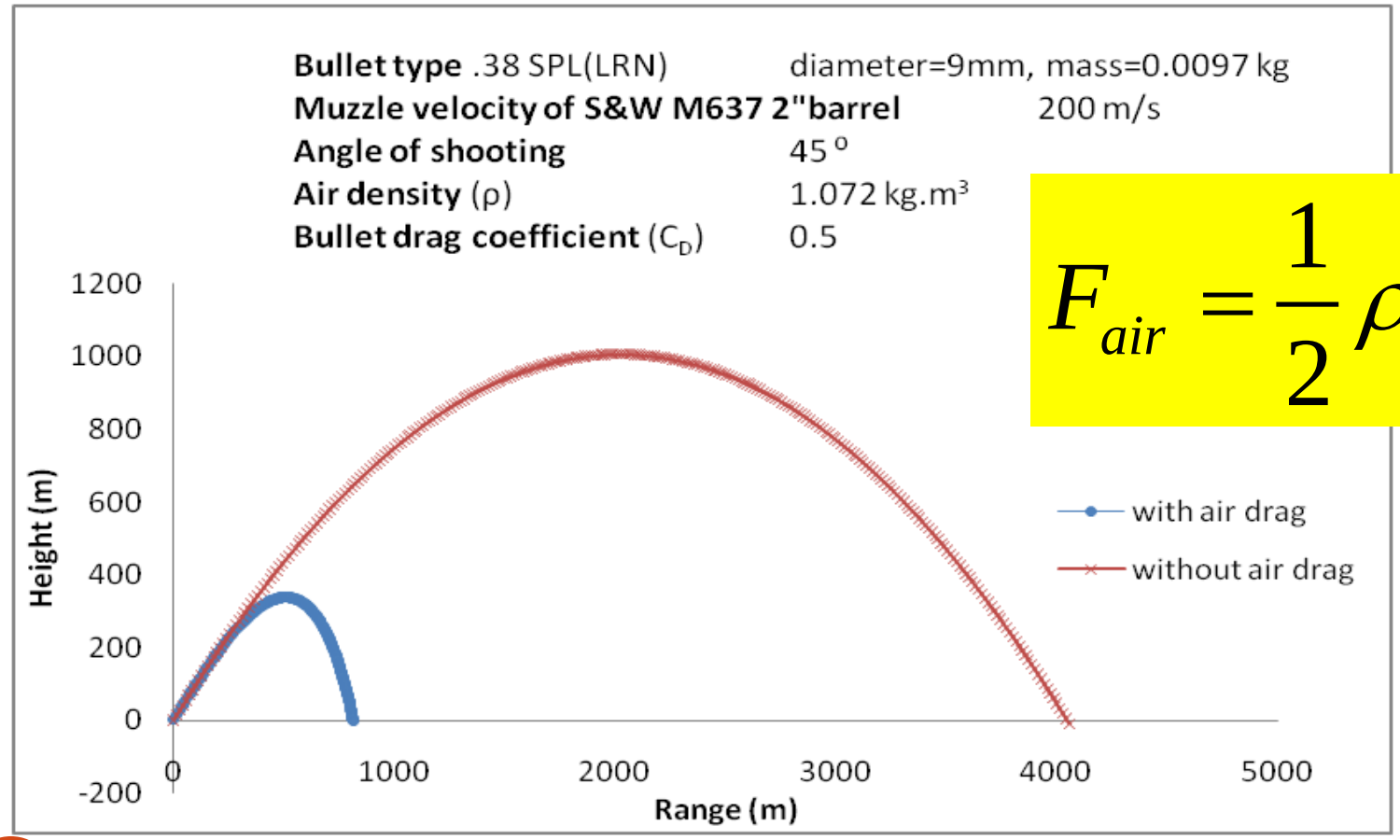
Gravity and drag



- Drag forces are many times that of gravity at high velocities, particularly when the object is **supersonic**.
- The gravity can simply be written as **G = mg**.
- The drag depends on many factors such as the **density of the atmosphere ρ**, **the cross-sectional area of the object A**, **the drag coefficient C_d** and the **square of the object velocity** $\mathbf{v = (v_x^2 + v_y^2)^{1/2}}$, i.e., $\mathbf{D = (1/2)\rho A C_d v^2}$

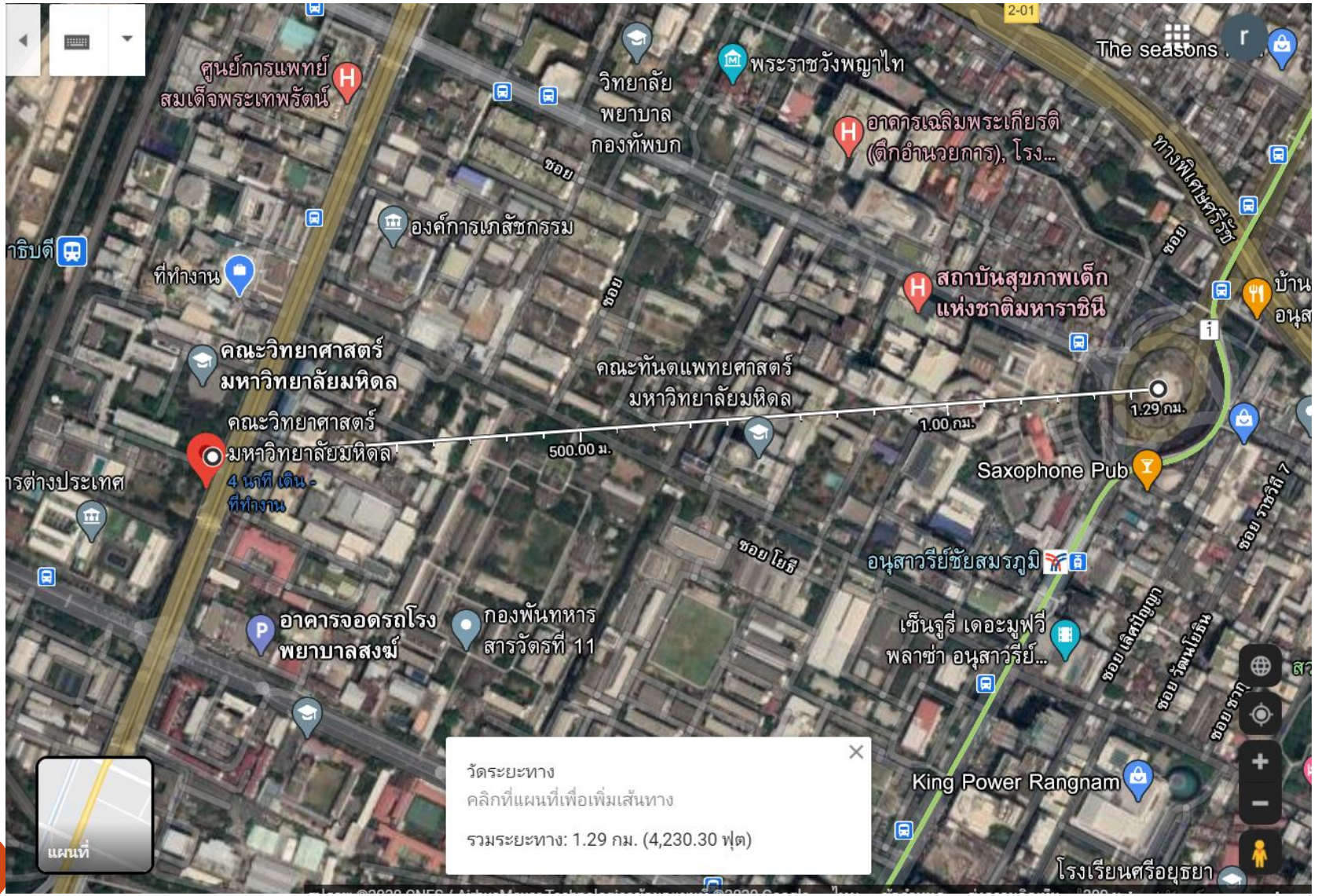
http://www.wired.com/wiredscience/2013/03/how-difficult-is-a-70-yard-field-goal/

Trajectory of a bullet with and without air drag



$$F_{air} = \frac{1}{2}\rho A C_d v^2$$

Google map แสดงระยะกระจัดจากคณะวิทยาศาสตร์ ไปยังอนุสาวรีย์ชัยฯ ระยะทางประมาณ 1.29 กิโลเมตร



Muzzle velocity

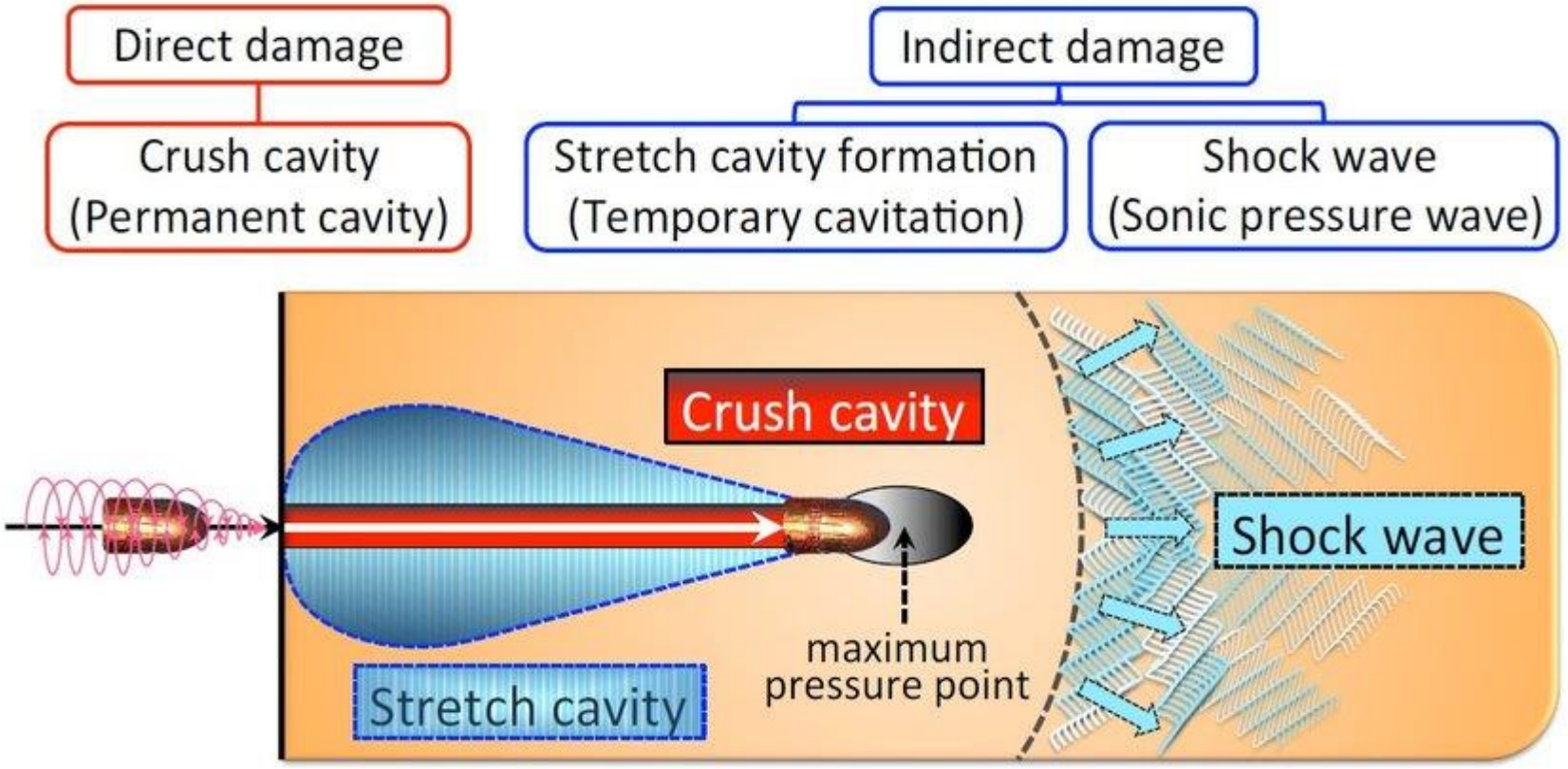
- The muzzle velocity is simply the speed at which a projectile leaves the muzzle of a weapon and can be measured by a chronograph.

Cartridge	m [g]	v_0 [m/s]	E_0 [J]	p [N·s]
.22 lr	2.5	330	140	0.8
9 × 19 mm Luger	8.0	350	490	2.8
.45 ACP	14.9	260	505	3.9
.44 Rem. Mag.	15.6	440	1510	6.9
.308 Winchester	9.5	830	3270	7.9
.375 H&H Magnum	17.5	835	6100	14.6
12/70 shotgun	~ 30	~ 400	~ 2400	~ 12

Muzzle velocity measured by a chronograph

https://www.tactical-life.com/combat-handguns/mastering-bullet-velocities/

Terminal Ballistics



- Two types of damages can occur.
- Direct damage due the bullet and indirect damage due to the tissue responses to the impacting bullet.

Tissue damaged by bullets

1. The passing bullet through human tissue transfer some kinetic energy to the surrounding tissue.
2. The tissue is radially thrown away leaving a **temporary cavity** much larger than the diameter of the bullet.
3. The temporary cavity results from the elasticity of the tissue which allows to regain its original structure after the bullet has passed.
4. There is also a **permanent cavity** which results from the destruction of tissue caused by the bullet itself.

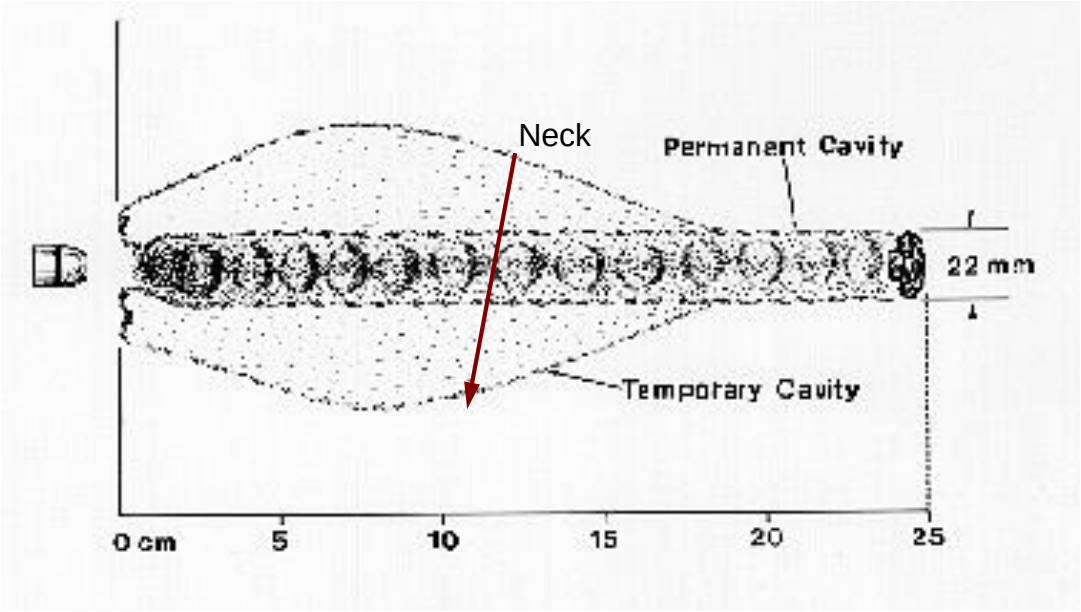
https://www.youtube.com/watch?v=4U40ArShS6M

Ballistic gelatin

- Ballistic gelatin closely simulates the density and viscosity of human and animal muscle tissue and is used as a standardized medium for testing the terminal performance of firearms ammunition.
- Use of the gelatin blocks can result in similar projectile depth of penetration and permanent damage to that observed in soft tissue (living and cadaveric).

https://www.youtube.com/watch?v=fgyZdrjSll4

Wound Profile from a handgun



.32 Cal. Silvertip Winchester

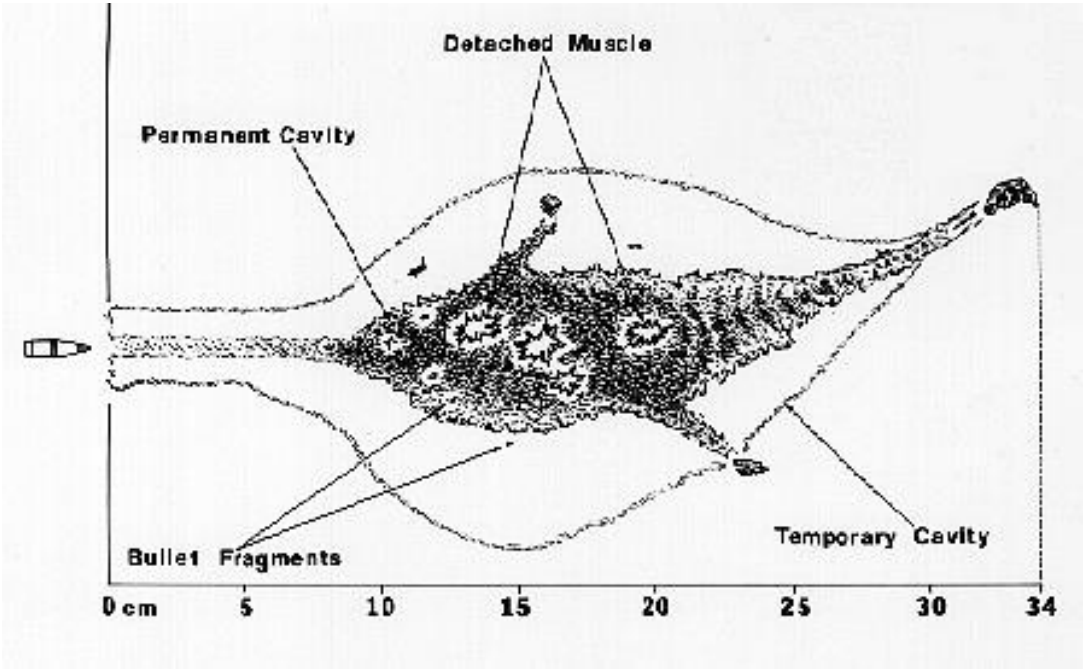
-soft lead

-Non-fragmenting, expanding

-Velocity: 940 fps (similar to present day .22 cal)

Fackler, et al. *Annals of Emergency Medicine*. 1996

Wound Profile from a rifle



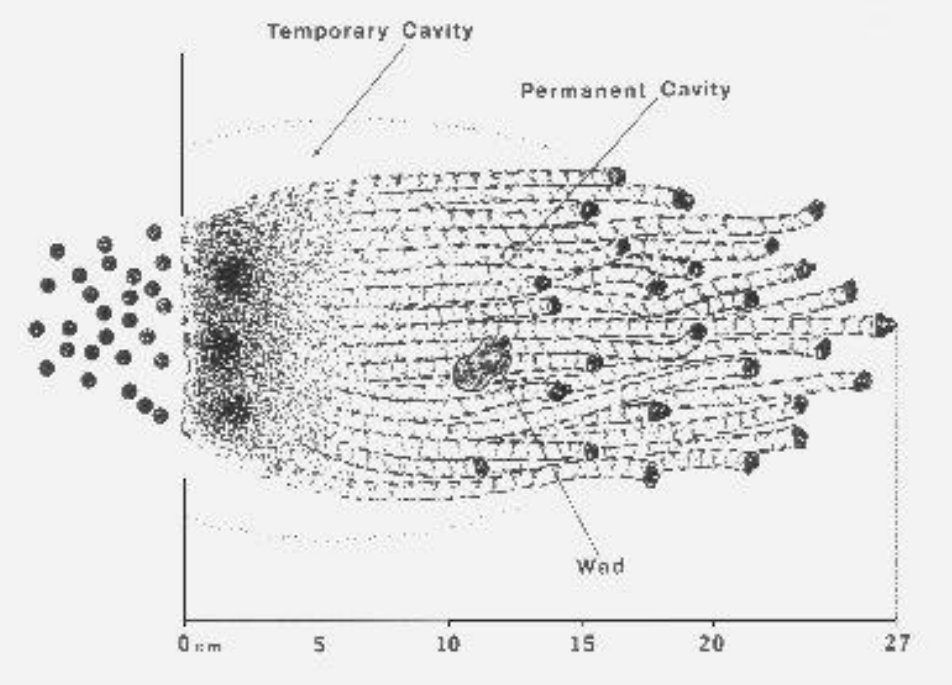
M-16 .22 Cal Military Rifle

-Full Metal Jacket

-Fragmenting rifle bullet

-Velocity = 3035 fps

Wound Profile from a shotgun

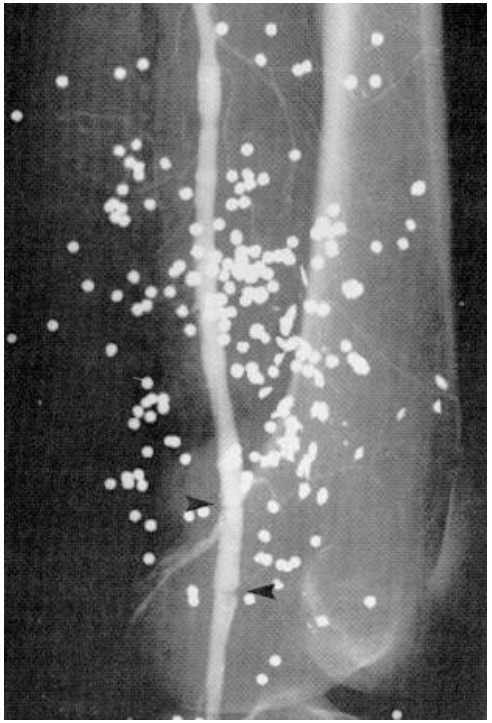


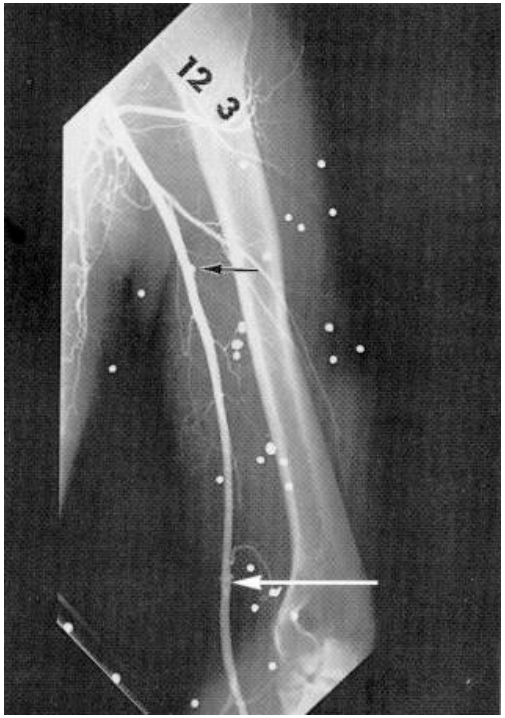
<u>12 gauge shotgun</u>

- 27 pellet #4 buck shot

- Velocity = 1350 fps

Shots from a shotgun inside a body





- The expansion of hollow point bullet when hit the target.
- This type of bullet is designed to stop within the body and transfer all its energy into the organs/tissues of the body.

http://www.guns.com/2014/03/26/federal-court-upholds-san-frans-tough-ammo-ban-gun-laws/

Pattern of tissue injury

- **Classification**
  - One of the commonest determinations of the forensic pathologist is the range of fire. Gunshot wounds are typically classified as:
    - Contact
    - Intermediate range
    - Distant range

Contact wounds

- Contact wounds – associated with contact of the barrel of the gun with the skin of the person.
- There are two types of contact wounds: **loose contact and tight.**
- A ragged stellate wound (deep cruciform tearing) can be found on bony part of the body.
- In some cases the impression of the muzzle can be seen imprinted onto the skin.

The contact gunshot entrance wound is caused by high pressure gases which follow the bullet and burst back out through the bullet entry hole.

http://www.forensicindia.com/forensic_pictures/index.htm

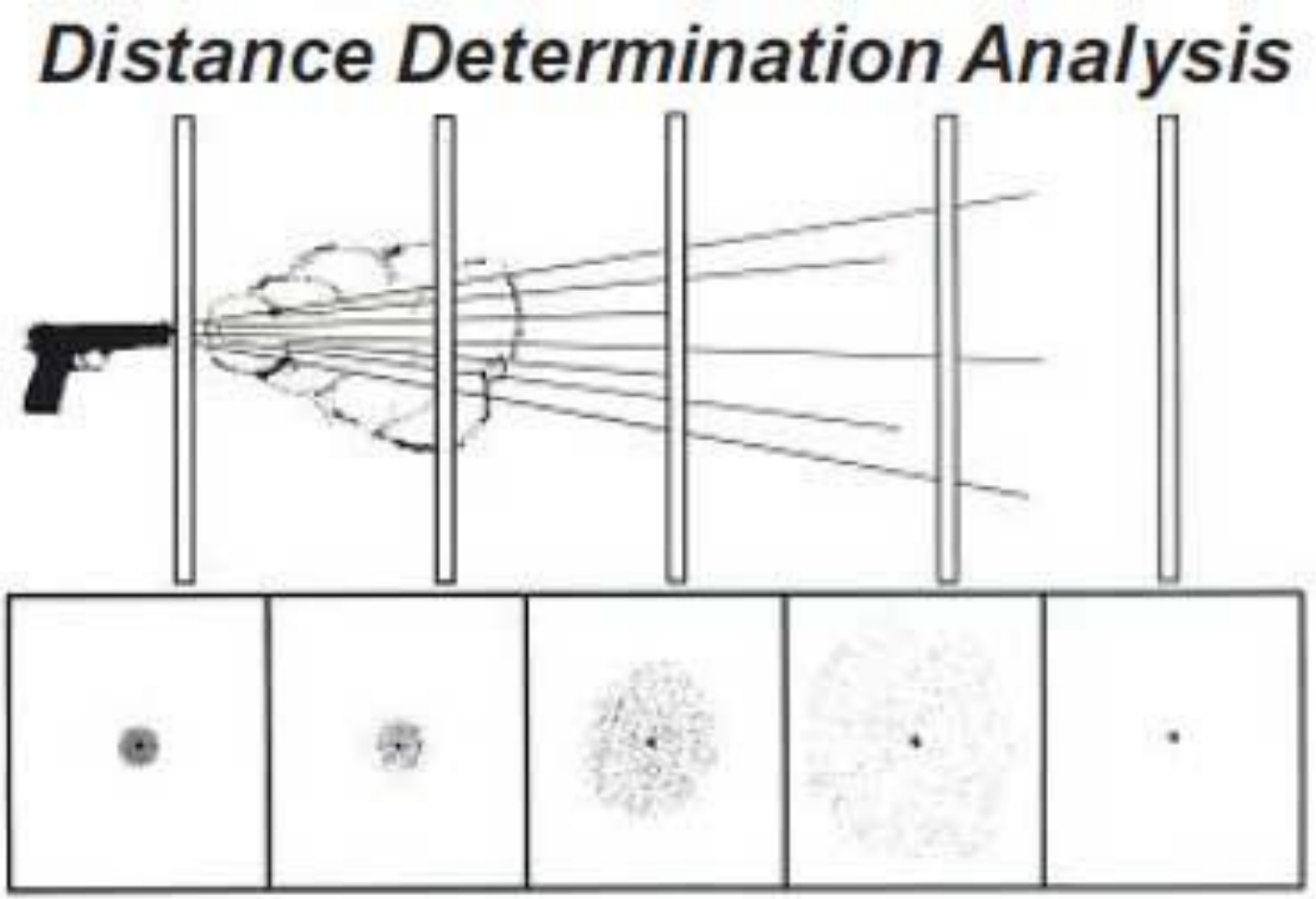
Intermediate range

- Intermediate range : wound at distances up to 1 m are characterized by a stippling of the skin around a circular entrance wound, caused by the burning primer and propellant residues (**gun shot residues : GSR**) impacting and sticking to the skin.

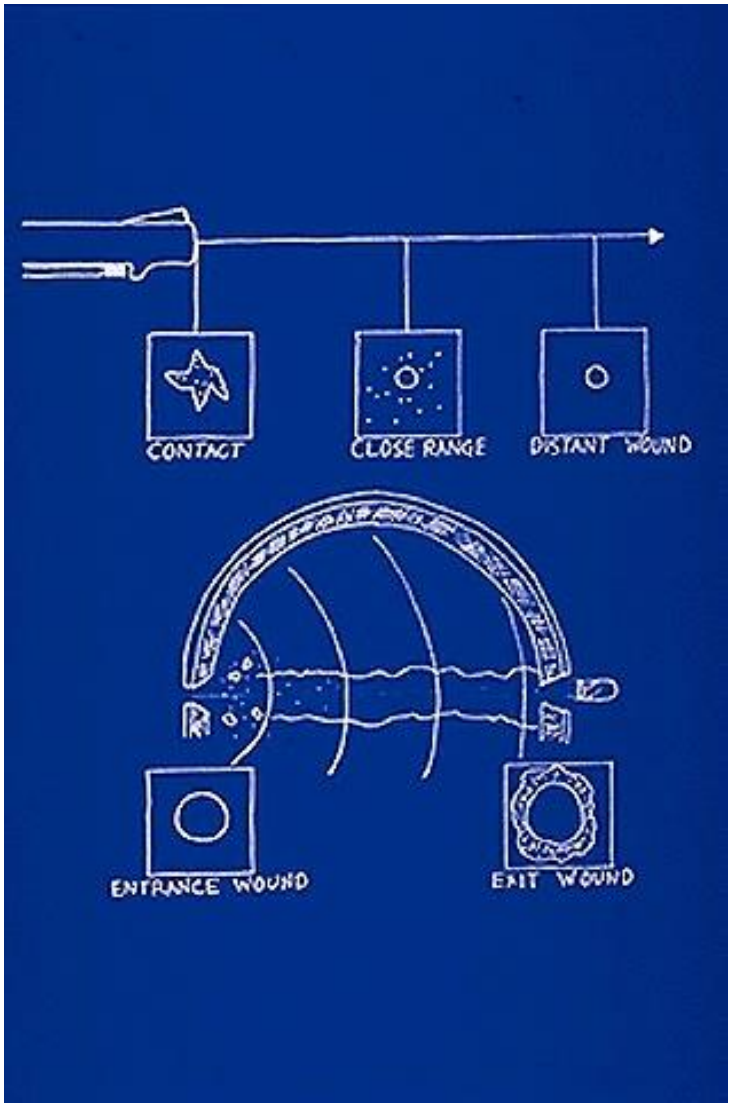
- The pattern is termed "**powder tattooing**".

- Density of tattooing is dependent on the distance & caliber.

Powder tattooing is seen in this intermediate range gunshot wound. The actual entrance site is somewhat irregular, because the bullet can tumble in flight.

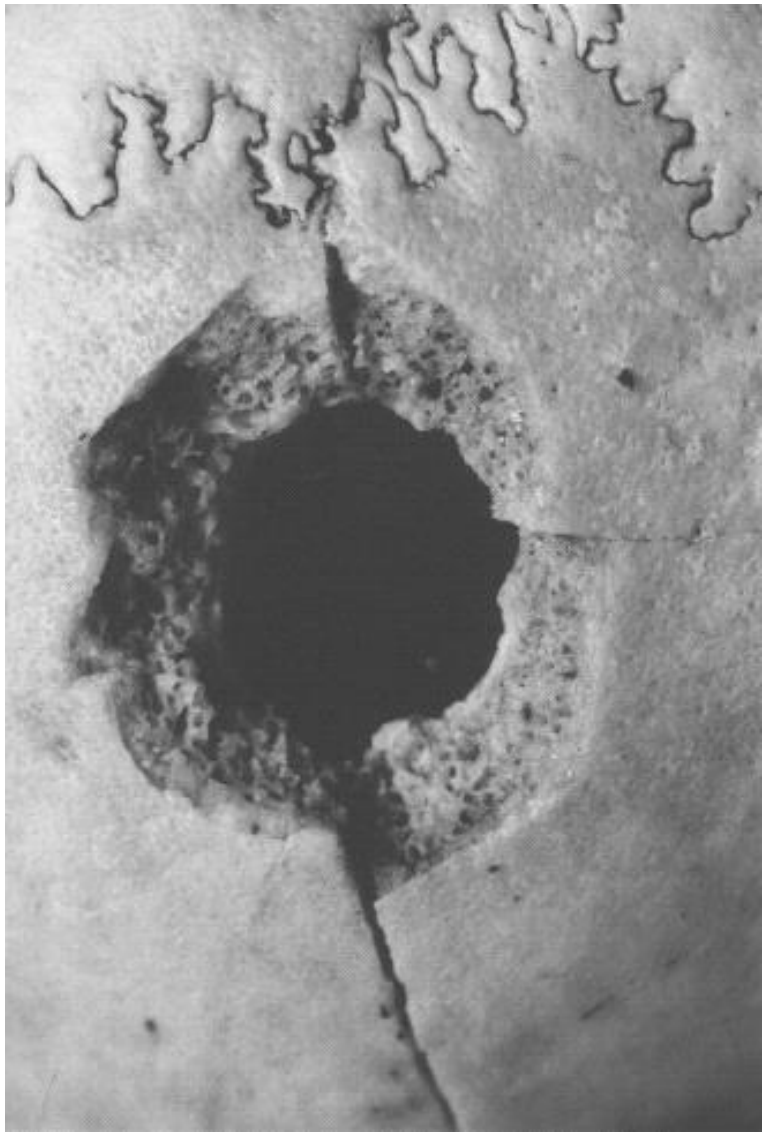


http://www.crime-scene-investigator.net/how-far-will-shooting-distance-determination-take-your-case.html



The upper diagram illustrates the basic differences between the **skin appearance** of a contact, close (intermediate), and distant range gunshot wound.

The lower diagram shows the **beveling** of the skull outward away from the direction of origin of the bullet.

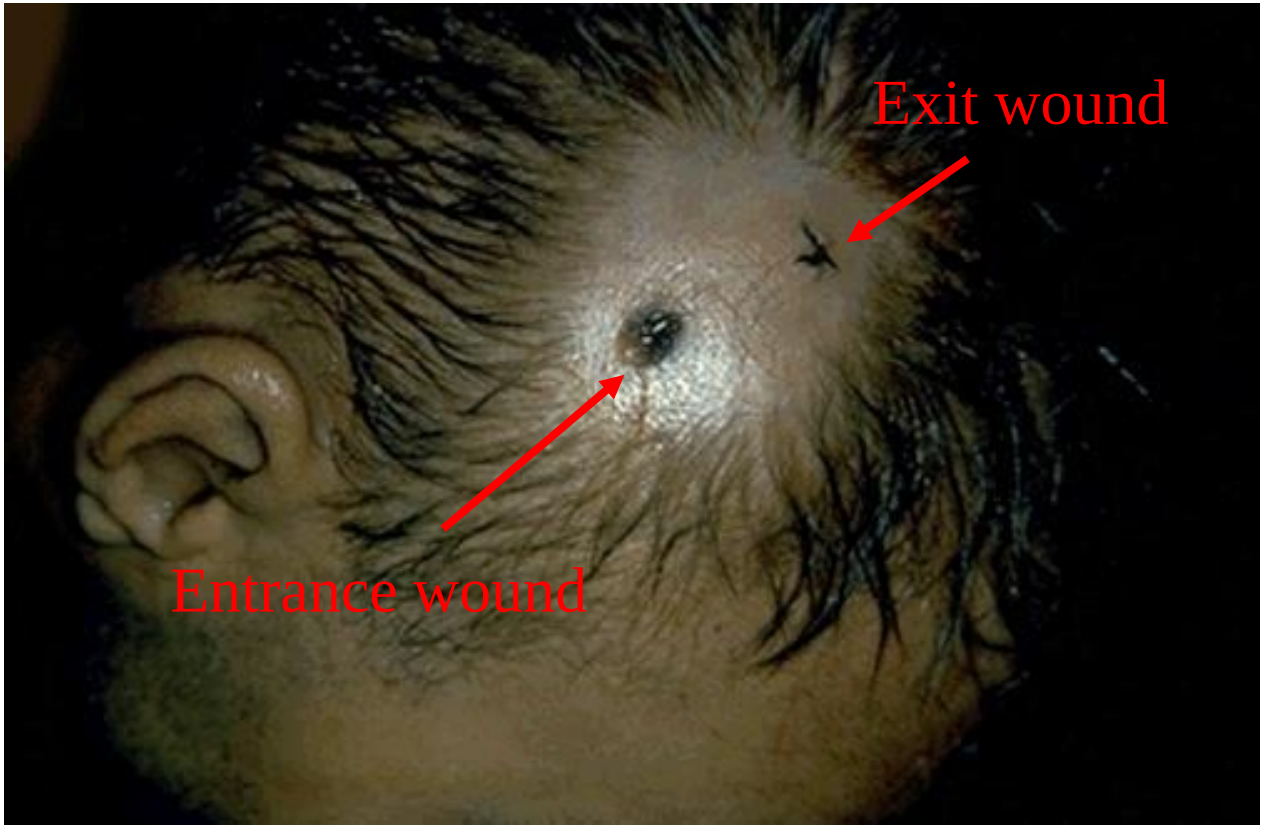


Bevelling of the skull

As the bullet exits the cranial cavity, the inner table (the inner compact layer of the bones covering the brain) appears "punched-out" with beveling on the outer table.

http://www.southampton.ac.uk/~jb3/bullet/gsw.html

Exit wound



Displayed here is an entrance at the left and an exit at the right. This particular bullet struck at an angle to produce the **ovoid entrance**. Exit wounds vary considerably in size and shape because the bullet can be deformed in its transit through the body.

Firearm identification

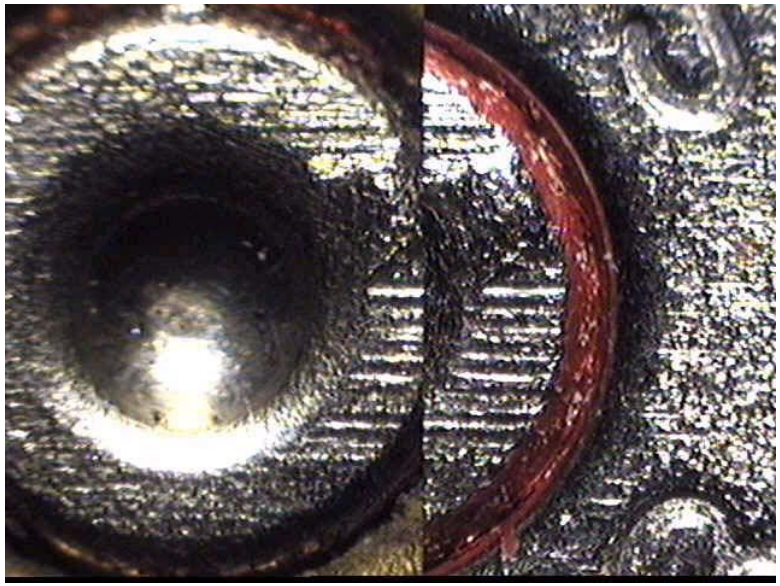
- The basis of firearms identification is that no two firearms produce the exact same marks on a fired bullet or cartridge.
- Comparison of bullets involves ″class″ and ″individual″ characteristics.

Examination of cartridges

- A process similar to the one use in bullet identification is used in identifying cartridge cases. Cartridge cases are the cases that house the bullet in the firearms before it is discharged.

Comparison microscope

- Some of the marks used to individualize a cartridge are shown below.



Marks left on Cartridge Case Near Firing Pin

Advanced forensic techniques

- In the absence of identifiable striations, bullet-firearm linkage cannot be established. The portion of the bullet carrying faint scratches, if any, may be examined for presence of transferred metal of barrel by Scanning Electron Microscope – Energy Dispersive X-ray (SEM-EDX).

- SEM-EDX gives both morphology and elemental compositions of the gunshot residue.

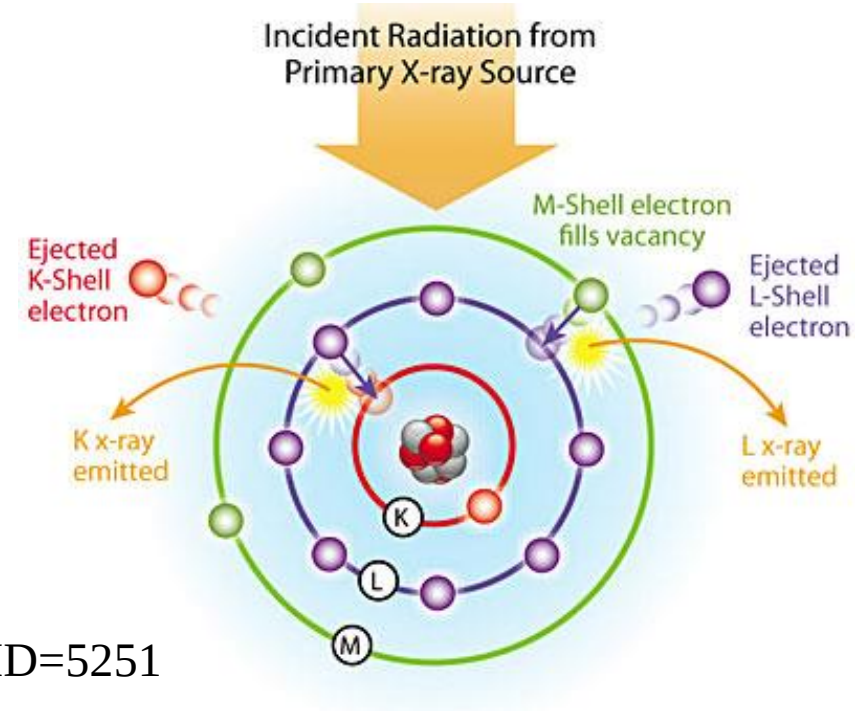
Scanning electron microscopy (SEM)

- SEM can reveal the actual surface details of the particles examined, for comparison with known examples of gunshot residue (GSR) primer.

- The large particles of partially burned powder and the spheres of residue can be distinguished from contaminant materials.

Energy dispersive X-ray analysis (EDX)

- An X-ray analyzer can be beamed directly onto the particles, so that the energy dispersive pattern (EDX) can be generated, giving the elemental composition of the particles.



https://www.azom.com/article.aspx?ArticleID=5251

OHT 9.11

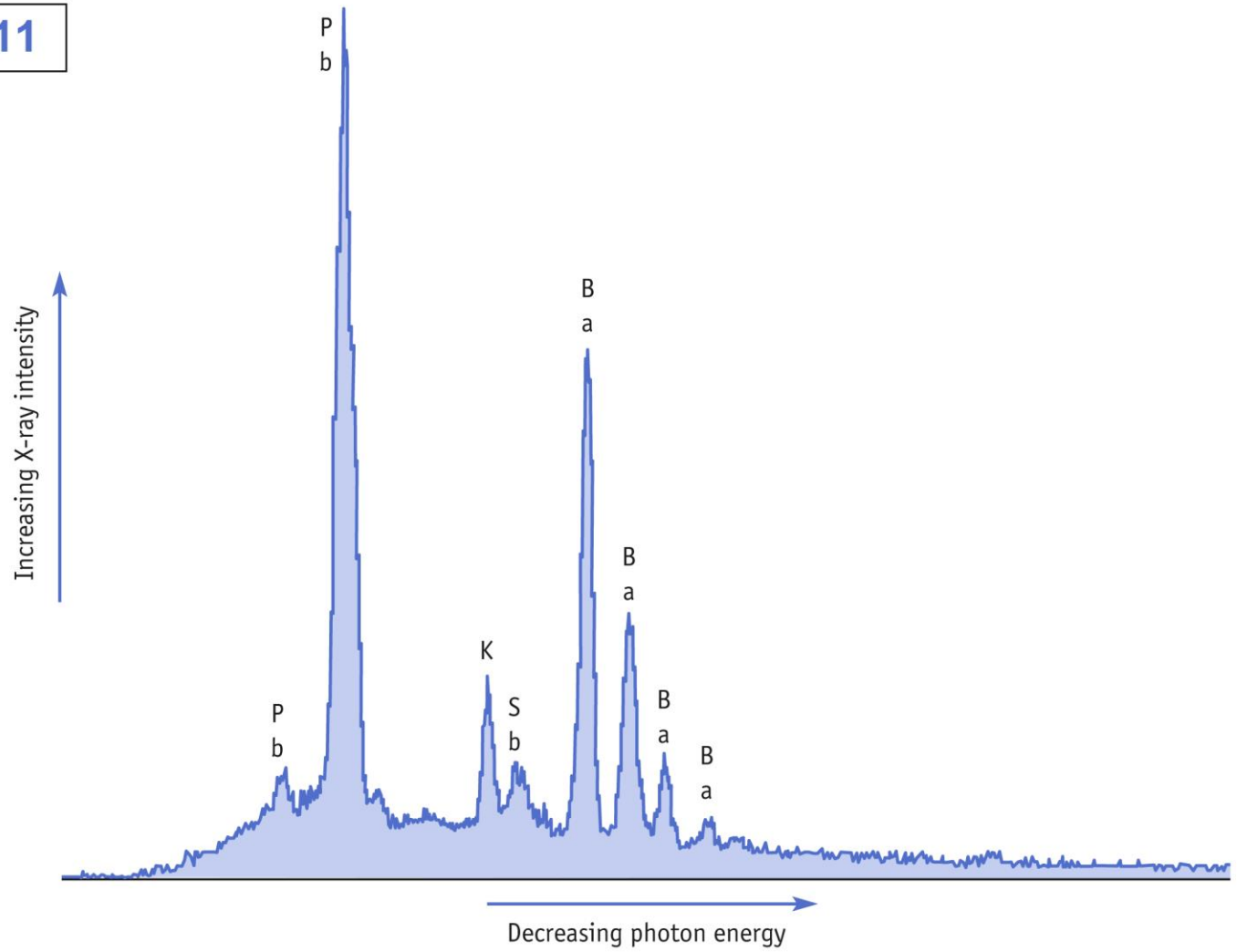


Figure 9.10 The elemental composition of a particle of gunshot residue as revealed by EDX during SEM-EDX analysis

Prepared by Derek Lowe, Staffordshire University, UK.

References

1. Brian J Heard, “Firearms and ballistics : examining and interpreting forensic evidence”, 2ed, Wiley-Blackwell, 2008.
2. B Karger and B P Kneubuehl, “On the physics of momentum in ballistics: can the human body be displaced or knocked down by a small arms projectile?”, Int J Legal Med, 109, p 147 -149, 1996.
3. L C Haag, “Shooting incident reconstruction”, Academic press, 2006.