



Bloodstain Pattern Analysis

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What is a Bloodstain Pattern Analysis?

- “A bloodstain pattern analysis is the study of the shapes, sizes, and locations of bloodstains in order to provide an interpretation of the physical events that gave rise to their origin.”
- In short, it’s a tool that can be used to help reconstruct a blood letting event.



Bloodstain Pattern Analysis (BPA)

- BPA is a specialty within the forensic identification field.
- In Ontario, the majority of analysts are police officers who are assigned to the Forensic Identification Section/Unit within their respective police service. (The Center of Forensic Sciences is currently providing this service on a limited basis.)
- The Ontario Provincial Police provide all forensic services, including bloodstain pattern analysis, for those municipal police services in Ontario who do not have this capability.
- There are approximately 30 active BPA analysts in Canada. About 18 of those analysts work in Ontario.



Bloodstain Pattern Analysis Training

- The Ontario Police College in Aylmer, Ontario provides a certification process for Bloodstain Pattern Analysts. This is available to any police agency or forensic lab worldwide.
- In order to receive certification, the candidate must successfully complete the following:
 - 1) A *Basic Bloodstain Pattern Recognition Course* (40 Hrs)
 - 2) A *Math and Physics Course for BPA* (40 Hrs)
 - 3) An *Advanced Bloodstain Pattern Analysis Course* (40 Hrs)
- The candidate must also enter into an **understudy program** in which he/she is mentored by a certified analyst.
 - Level I (observe mentor process scenes)
 - Level II (process scene under supervision)
 - Level III (process scenes alone)

Bloodstain Pattern Training

The understudy program involves;

- **Mandatory reading and experimentation.**
- **Written examination**
- **Oral certification board** at the Ontario Police College.



Morning; getting qualified before the “judge”

Afternoon; presenting your mock scene case and conclusions.



Bloodstain Pattern Training

- If the candidate satisfies the members of the Mock Trial, who are all certified analysts, that he/she has sufficient knowledge, training, and experience to perform the duties of an analyst, then they are certified by OPC.
- Ultimately, it will be the courts who will decide whether the witness is able to offer opinion (expert) evidence in the field of ***“Bloodstain Pattern Analysis.”***
- The Royal Canadian Mounted Police have an internal certification program for their Bloodstain Pattern Analysts.
- All required courses must be recognized and satisfy the requirements of the Ontario Police College.



First Use of Bloodstain Pattern Analysis

- The first recorded **Canadian** case in which expert testimony was utilized in regards to bloodstain pattern analysis was *Regina vs Sparrow* (1976). The case involved a homicide from Gloucester, Ontario. Herbert MacDonell, Ph.D. testified on behalf of the Crown. He gave evidence about the age of bloodstains on a vehicle.
- MacDonell is recognized as the grandfather of bloodstain pattern analysis and wrote the first modern publication in 1971 entitled “Flight Characteristics and Stain Patterns of Human Blood.” He began conducting the first formal training courses in 1973. Many of the terms, theories, and basic experiments taught today were developed by Dr. MacDonell.



First Use of Bloodstain Pattern Analysis

- The first notable case in the **United States** in which bloodstain evidence was used was the case of the *State of Ohio vs Samuel Sheppard*.
 - In 1955 Dr. Paul Kirk submitted an affidavit based on his examination of the scene. Sheppard was convicted.
 - In 1966 Sheppard was granted a new trial and was acquitted.
 - After Dr. Kirk's death, DNA testing on a stain scraped from the closet door came back to an unidentified male.



Sam Sheppard



Dr. Paul Kirk



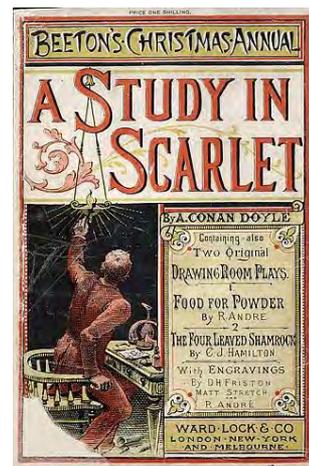
History of BPA

- Although the use of bloodstain evidence at crime scenes was only recognized in North America during the latter part of the twentieth century, references can be found throughout history, primarily in Europe.
- The Bible; God to Cain; “*Your brother’s blood cries out to me from the ground.*”
- The Roman Jurist Quintilianus (35 to 118 AD) questioned how the defendant’s hands could become so bloody following a stabbing with a sword that they would leave hand prints on a wall that were the same density from beginning to end, thus appearing to be staged.



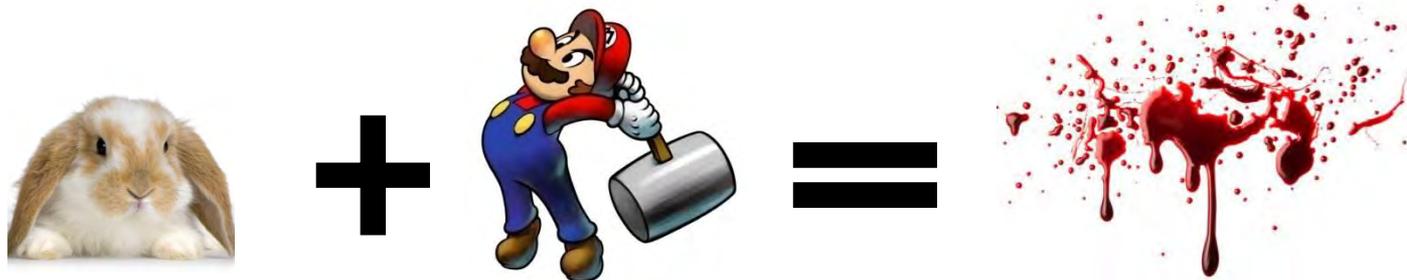
History of BPA

- In 1514 an accused named Richard Hunne was found hanging in his cell. It was noted that *“the great plenty of blood was shed before he was hanged.”*
- William Shakespeare (1582-1616) makes reference to blood in MacBeth (Act II Scene III) *“What hands are here! Ha! They pluck out my eyes. Will all great Neptune’s ocean wash this blood clean from my hands.”*
- In 1887 Sir Arthur Conan Doyle wrote about the famed fictional detective Sherlock Holmes in “A Study in Scarlet.” In the story, Holmes discovered a reliable reagent for blood and in the scene examination, he notes *“the gouts and splashes of blood which lay all around.”*



History of BPA

- 1893 - Hans Gross described the relevance of the shapes and distortions of bloodstains. His work was translated into English in 1906.
- 1895 - Eduard Piotrowski wrote “**Origin, Shape, Direction, and Distortion of the Bloodstains Following Head Wounds Caused By Blows.**”



- 1904 - Hans Gross wrote “Criminal Investigations.” In this book he noted that the **directionality of a bloodstain could be determined by its shape.** He also discussed the documentation and collection of this evidence.



History of BPA

- 1939 - Balthazard et al determined the angle of impact of a projected bloodstain from the width to length ratio.
- 1955 - Dr. Paul Kirk and the Sam Sheppard Case.
- 1971- Publication by MacDonell following a 1969 L.E.A.A grant (Law Enforcement Assistance Administration)
- 1973 - MacDonell publishes “Laboratory Manual on the Geometric Interpretation of Human Bloodstain Evidence” and conducts his first formal training course in Jackson Mississippi using that manual.
- 1978 - The R.C.M.P. begin a bloodstain program and send Sgt Ross Read to Corning New York to receive his basic training from MacDonell.





History of BPA

- 1982 - The R.C.M.P. approach Fred Carter, Ph.D who was a professor of physics at Carleton University. They requested that he assist Ken Hardy with the instruction of physics. Dr. Carter develops an interest in bloodstain pattern analysis.
- 1983 - “**The International Association of Bloodstain Pattern Analysts**” (I.A.B.P.A.) was created to promote the field of bloodstain pattern analysis through research, training, and education. Today there are approximately 800 members worldwide.





History of BPA

- 1983 - Barton Epstein and Terry Laber write “Experiments and Practical Exercises in Bloodstain Pattern Analysis.”
- 1983 - MacDonell writes a comprehensive book entitled “Bloodstain Pattern Interpretation.” This book was based on his research through the L.E.A.A. grant from 1969 to 1971. This book would be updated in 1993 and was the first of many books to be written specifically about bloodstain pattern analysis.
- 1989 - Dr. Carter develops a computer program to assist in the analysis of projected bloodstain patterns

BackTrack™

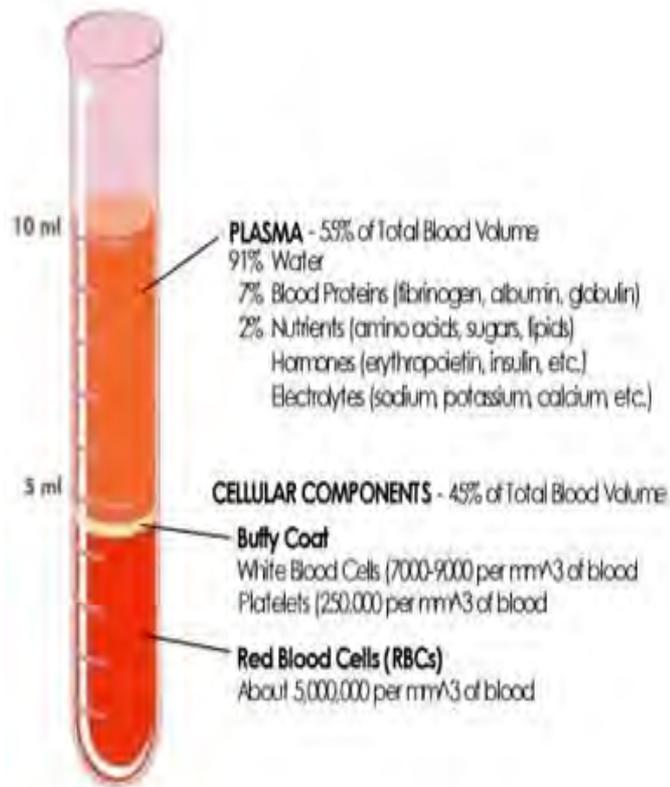


The Function and Composition of Human Blood

- Blood is defined as the “circulating tissue of the body.” The fluid and its suspended formed elements are circulated by the heart through the arteries, veins and capillaries.
- Blood is the medium by which oxygen and nutritive materials are transported to the tissues and carbon dioxide and various metabolic products are removed for excretion. (Stedman’s Medical Dictionary)

The Composition of Human Blood

- Blood is approximately 55% liquid and 45% solid material (formed elements).
- The liquid portion is known as “**Plasma**” when the blood is not clotted and as “**Serum**” when the blood is actually clotting. The liquid portion is comprised of:
 - **91 % Water**
 - **7 % Protein** (Albumine/Globulins/Fibrogen)
 - **2 % Other Solutes** (Metabolic End Products/Food Materials/Respiratory Gases/Hormones)
 - ****Approximate Values****





The Composition of Human Blood

- The formed elements are suspended, not dissolved, and consist of:
- **Red Blood Cells (Erythrocytes)**
- **White Blood Cells (Leukocytes) – contains DNA**
- **Platelets**
- The quantity of the formed elements vary by sex but on average one cubic millimeter of blood in a healthy adult will contain 4.3 to 5.8 million red blood cells, 5000 to 10,000 white blood cells, and 250,000 to 400,000 platelets.



Volume of Blood

- To maintain blood pressure and circulation, the volume of blood in a human body must be maintained at approx. **8% of the body weight**.
- Average blood volume for humans is approx. 5-6 litres.
- Units of blood (used during transfusions) = 500 ml (0.5 liters) in volume.
- **At rest**, it takes about 1 minute for the entire blood volume to circulate through the body.

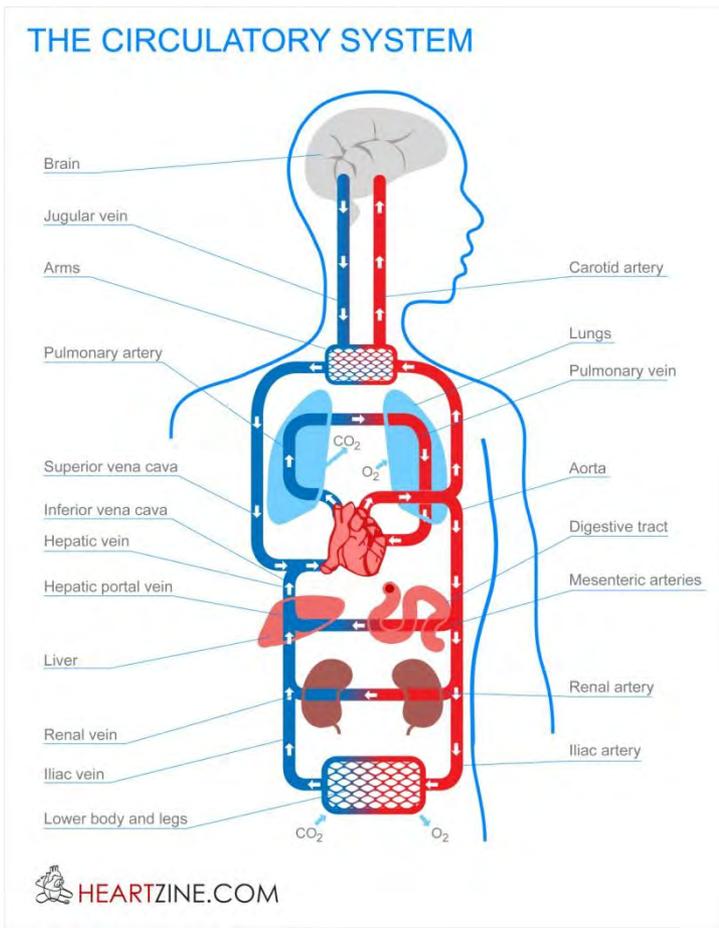
Blood Loss

- **10% of blood volume** = no problem for a normally healthy person
- **15-25% of blood volume** = drop in blood pressure – person needs medical help
- **> 25%** = life-threatening (severe shock at 30%)
- **50% of blood volume in a short period** = will generally result in death (BP drops to the point that life can't be maintained).



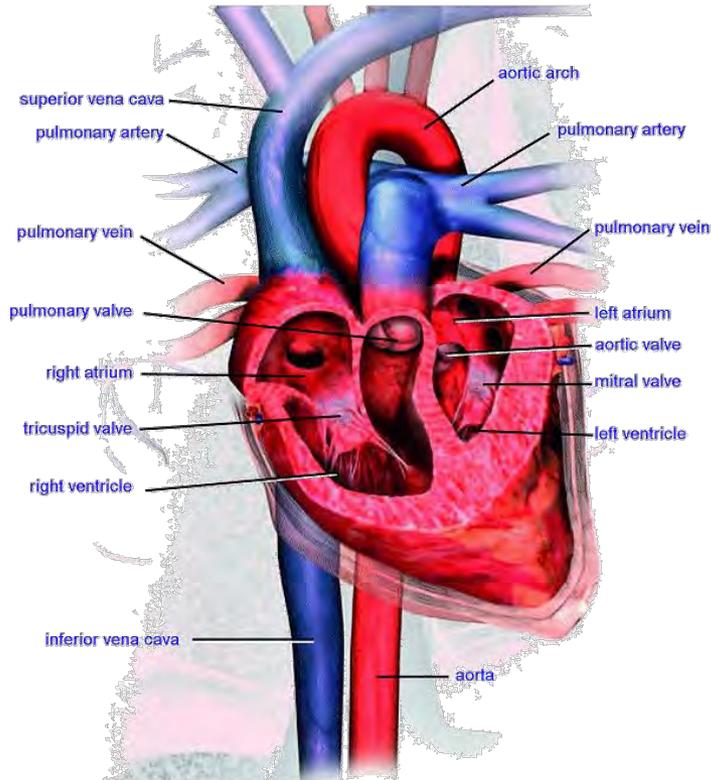
Vascular Anatomy

- Systemic and Pulmonary Circulations
 - Arteries
 - Capillaries
 - Veins



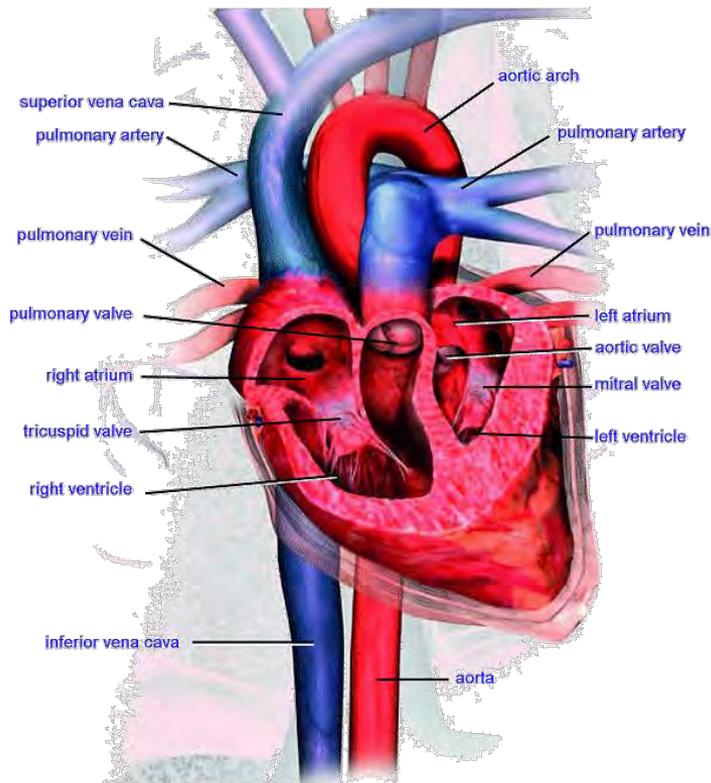
Systemic Circulation

- **Systemic circulation** supplies nourishment to all of the tissue located throughout your body, with the exception of the heart and lungs because they have their own systems (coronary and pulmonary).
- High pressure system
- Responsible for most bleedings



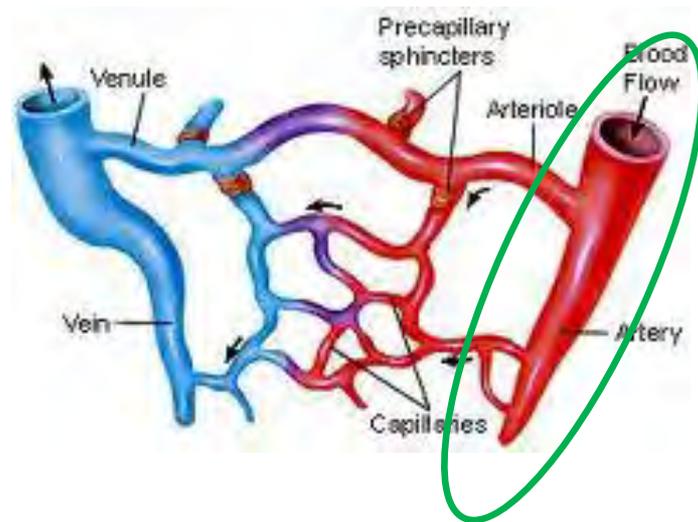
Pulmonary Circulation

- **Pulmonary circulation** is the movement of blood from the heart, to the lungs, and back to the heart again.
- Carries un-oxygenated blood
- Gas and nutrient exchange with tissues
- Microscopic hemorrhages (petechiae)
- No significant blood loss



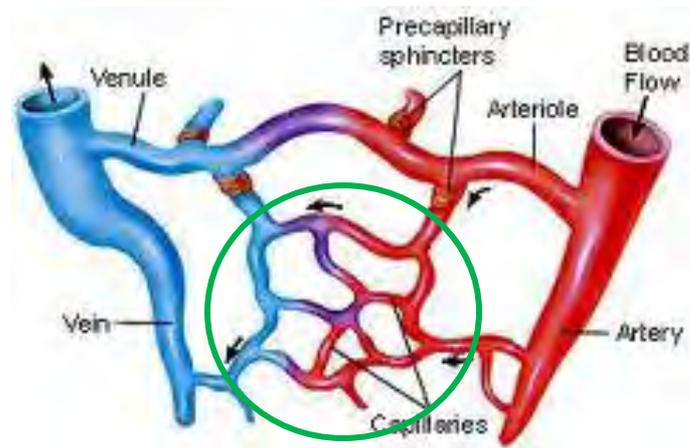
Arteries

- The heart pumps blood out through one main artery called the dorsal aorta. The main artery then divides and branches out into many smaller arteries so that each region of your body has its own system of arteries supplying it with fresh, oxygen-rich blood.
- Help keep blood pressure consistent.
- The arteries deliver the oxygen-rich blood to the capillaries where the actual exchange of oxygen and carbon dioxide occurs.
- Usually involves significant blood loss.



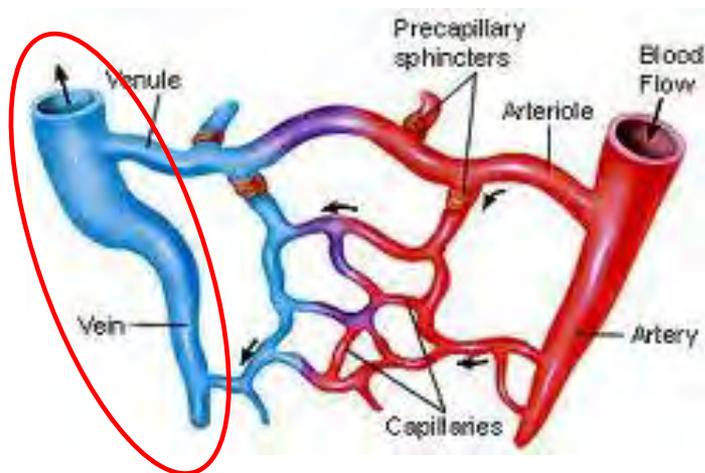
Capillaries

- A capillary is an extremely small blood vessel located within the tissues of the body, that transports blood from arteries to veins.
- Microscopic
- Gas and nutrient exchange with tissues
- Microscopic hemorrhages (petechiae) when damaged
- No significant blood loss
- Blood goes from the capillaries to veins



Veins

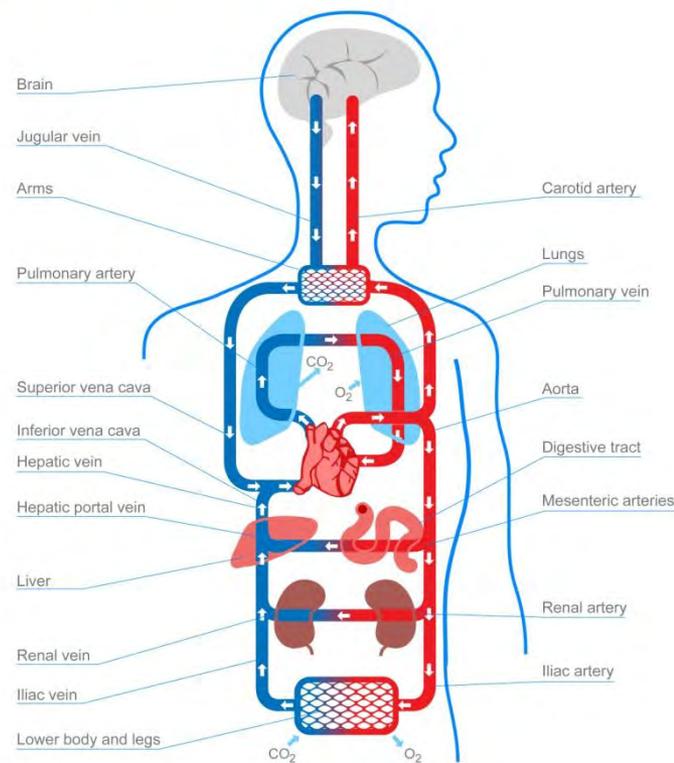
- A vein is an elastic blood vessel.
- Transports blood from various areas to the heart
- Four types;
 - Pulmonary; oxygenated blood from lungs to heart
 - Systemic; return deoxygenated blood from the rest of the body to the heart
 - Superficial; located close to the surface of the skin
 - Deep; located deep within muscle tissue, usually near arteries
- Slow flow rates



Flow of Blood

- Deoxygenated blood is transported through the **superior** (head and upper body) and **inferior** (lower body) **vena cava** into:
- The **right atrium** which flows into
- The **right ventricle** which flows into
- The left and right **pulmonary arteries** which transport the blood to the lungs.
- Carbon dioxide is removed and oxygen is absorbed by the red blood cells.

THE CIRCULATORY SYSTEM



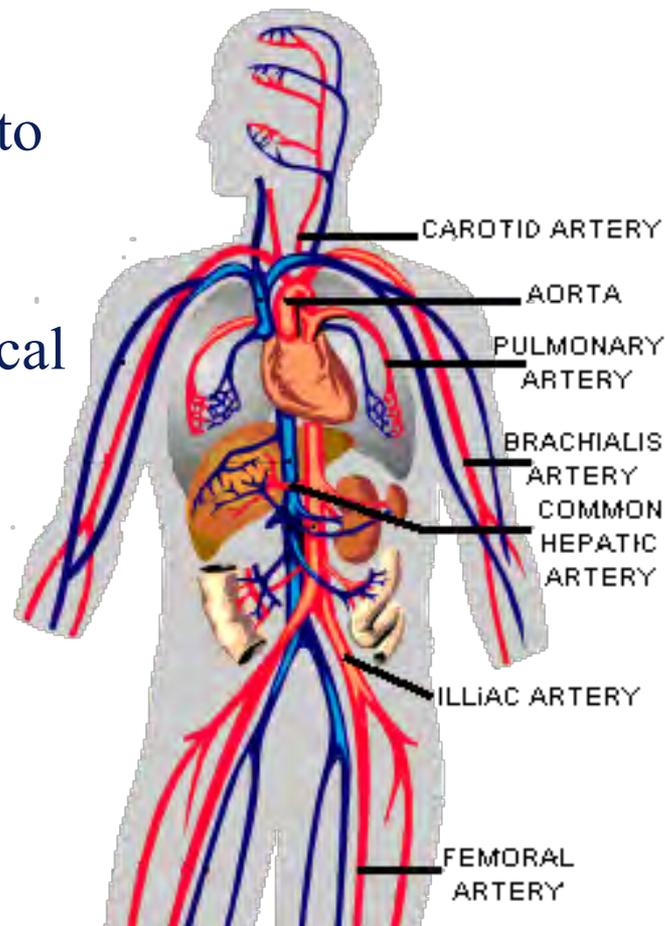


Blood Loss

- Blood can be lost either internally (intrinsic) or externally (extrinsic).
- Bleeding occurs either due to injury or disease.
- In BPA, we are concerned primarily with external blood loss, however, certain internal bleeding may also become evident outside of the body....e.g. gastro-intestinal bleed.

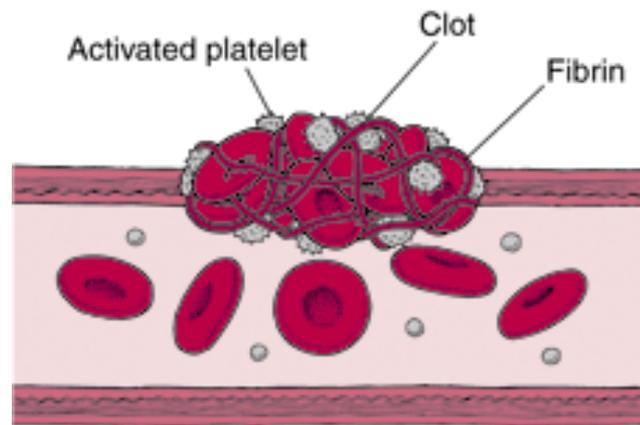
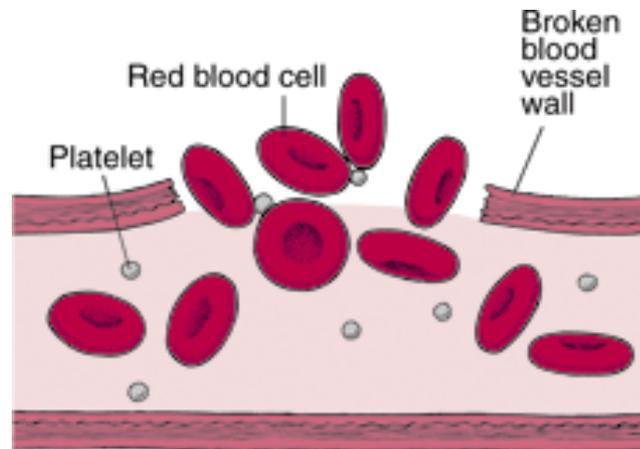
Blood Loss

- There are several regions on the body where major **arteries** are found close to the surface and when breached, will result in rapid blood loss and often certain death without immediate medical intervention.
- **Carotid** - Neck
- **Brachial** - Upper Arm
- **Radial** - Lower Arm/Wrist
- **Femoral** - Upper Leg/Thigh



Blood Clotting Characteristics

- Once bleeding is present, the body immediately begins the clotting process. This takes several minutes during internal bleeding while it is almost immediate during external bleeding.
- There are a total of **13 clotting factors** in the human blood. Once the clotting begins, a chain reaction occurs until ultimately fibrin is formed and simulates a “web” -like structure which attaches itself to the platelets and captures the red blood cells to prevent further escape. The serum (liquid portion) is separated and surrounds the clot.





A Bloodstain Pattern Analysis May Determine;

- **Location of an impact.**
- **The minimum number of impacts.**
- **The mechanism or object used to create a specific pattern.**
- **The position of person(s)/objects while they were shedding blood.**
- **Movement of person(s)/objects during the bloodshed.**
- **Movement of person(s)/objects after the bloodshed.**
- **Sequencing of events.**

Generally, an analysis may help corroborate, or refute what a witness, suspect, or victim may have told investigators.



The Four Basic Tenets of Bloodstain Pattern Analysis

1/ *Blood will behave according to the laws of physics.*

When it is in a liquid state, in motion, it will behave according to the laws of physical science known as ballistics. (The science of projectiles in motion).

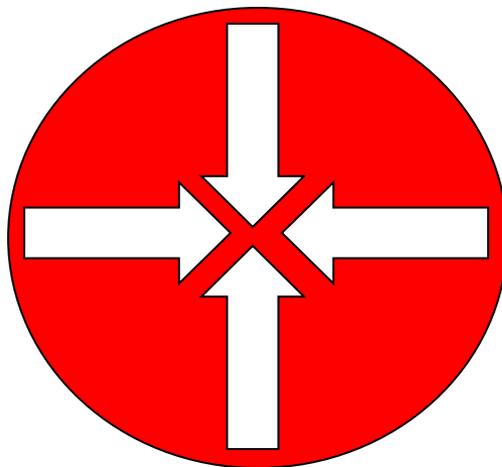
Characteristics of Blood - Surface Tension

- Surface tension is the property of a surface of a liquid that allows it to resist an external force.
- The elastic-like property of the liquid's surface makes it tend to contract due to the forces of attraction between the molecules of the liquid.
- The cohesive forces tend to resist penetration and separation.



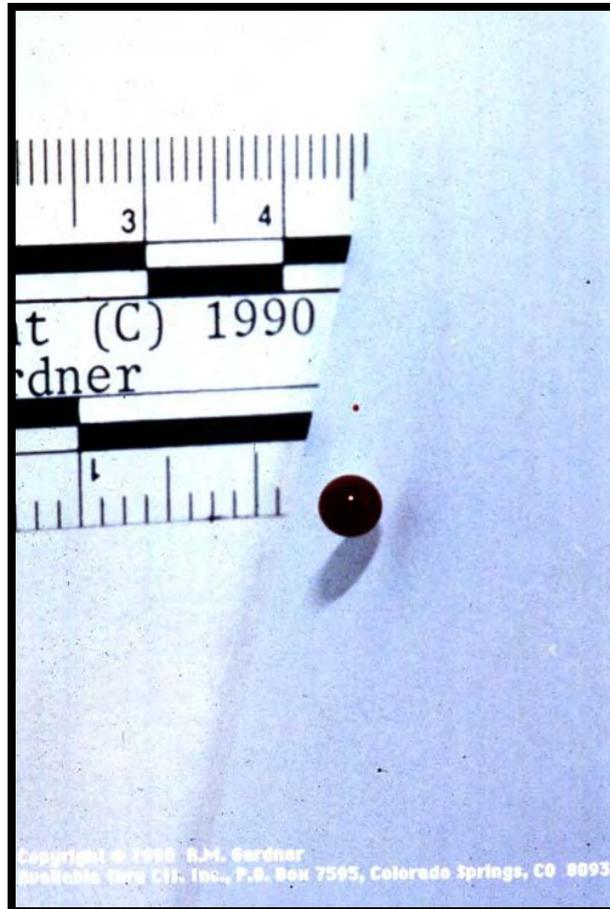
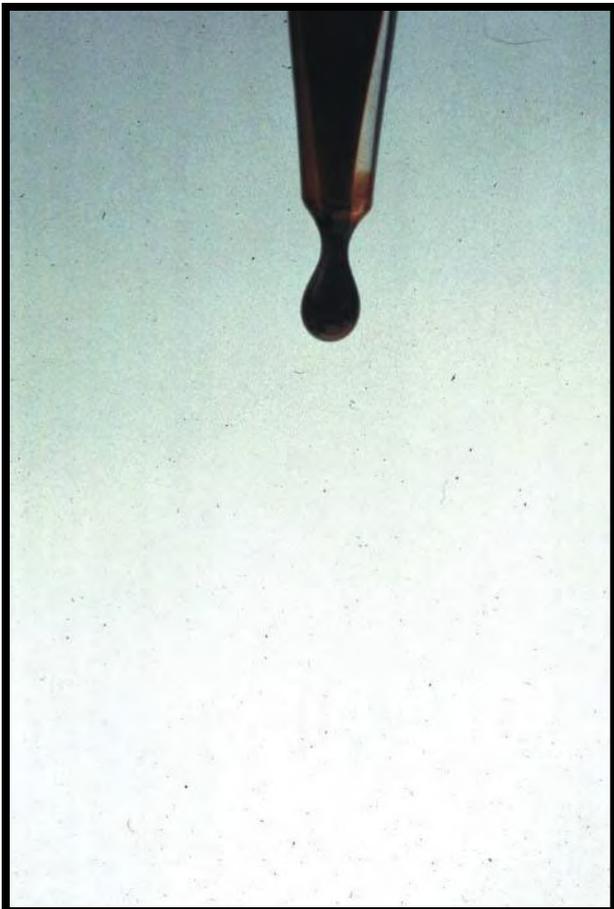
Characteristics of Blood - Surface Tension

- When a blood droplet is detached from its source, it is subject to surface tension and will assume a spherical shape.



- It will maintain its shape and direction unless acted upon by some other force.

Surface Tension



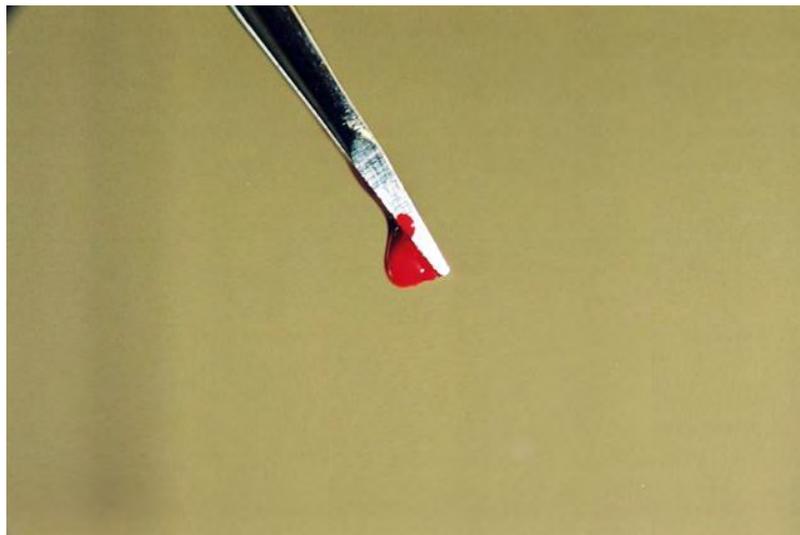
Surface Tension

The impact of the mallet randomly dispersed the exposed blood into hundreds of blood droplets.



Characteristics of Blood - Viscosity

- Viscosity; a fluid's resistance to flow. The flow of a liquid decreases as its viscosity increases.

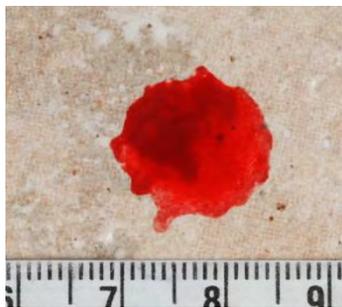
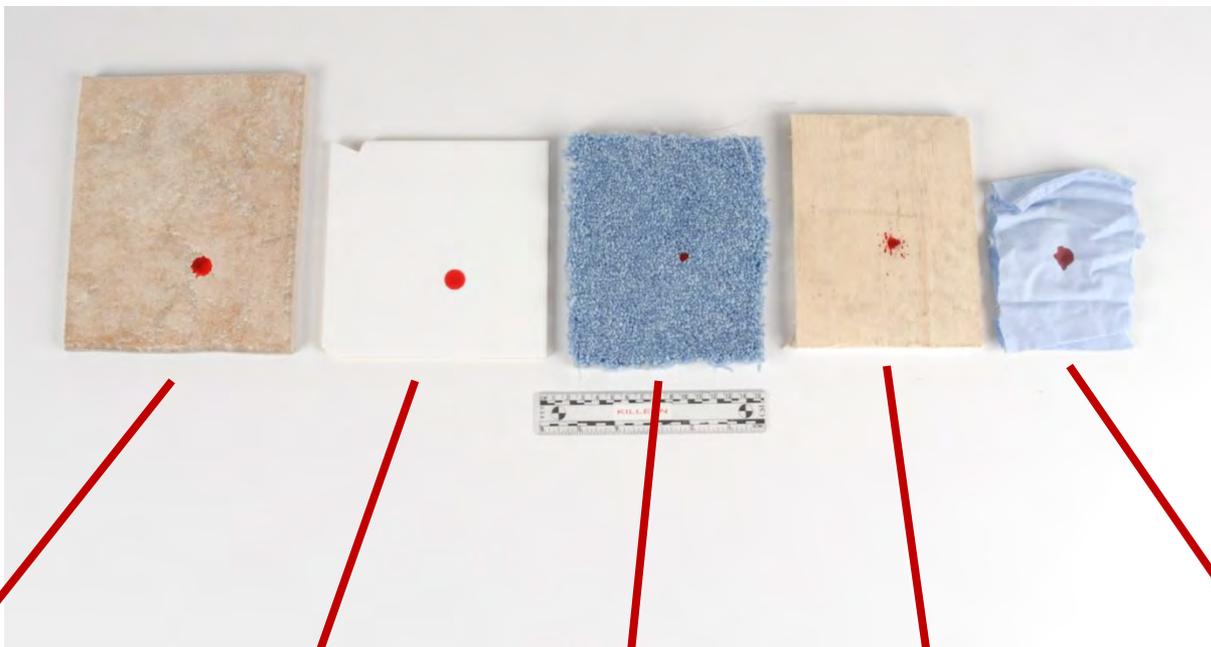


- The viscosity of blood helps it to retain its spherical shape when it is in the form of a blood drop.

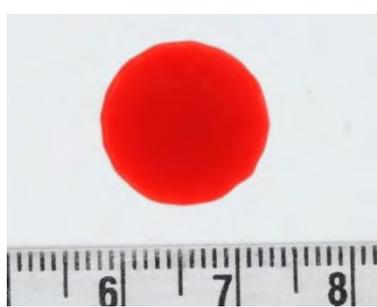


The Four Basic Tenets of Bloodstain Pattern Analysis

2/ The appearance of a bloodstain is dependent upon the surface it is deposited onto.



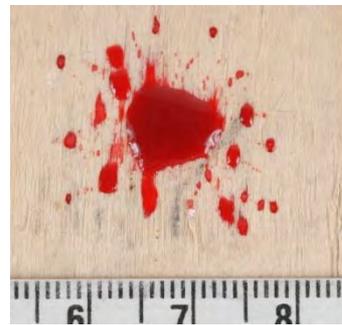
Rough Tile



Smooth Tile



Carpet



Plywood



70/30 Shirt

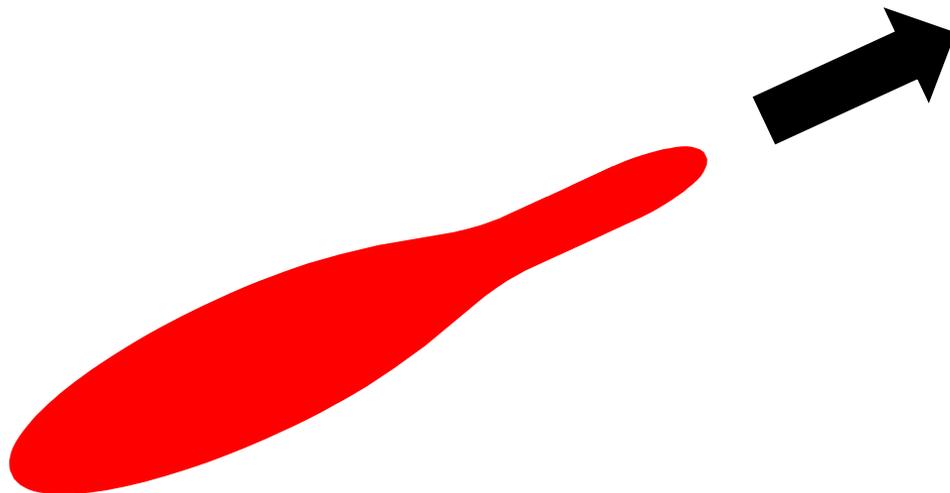


The Four Basic Tenets of Bloodstain Pattern Analysis

3/ You can usually tell the direction a bloodstain was moving by its appearance (shape).

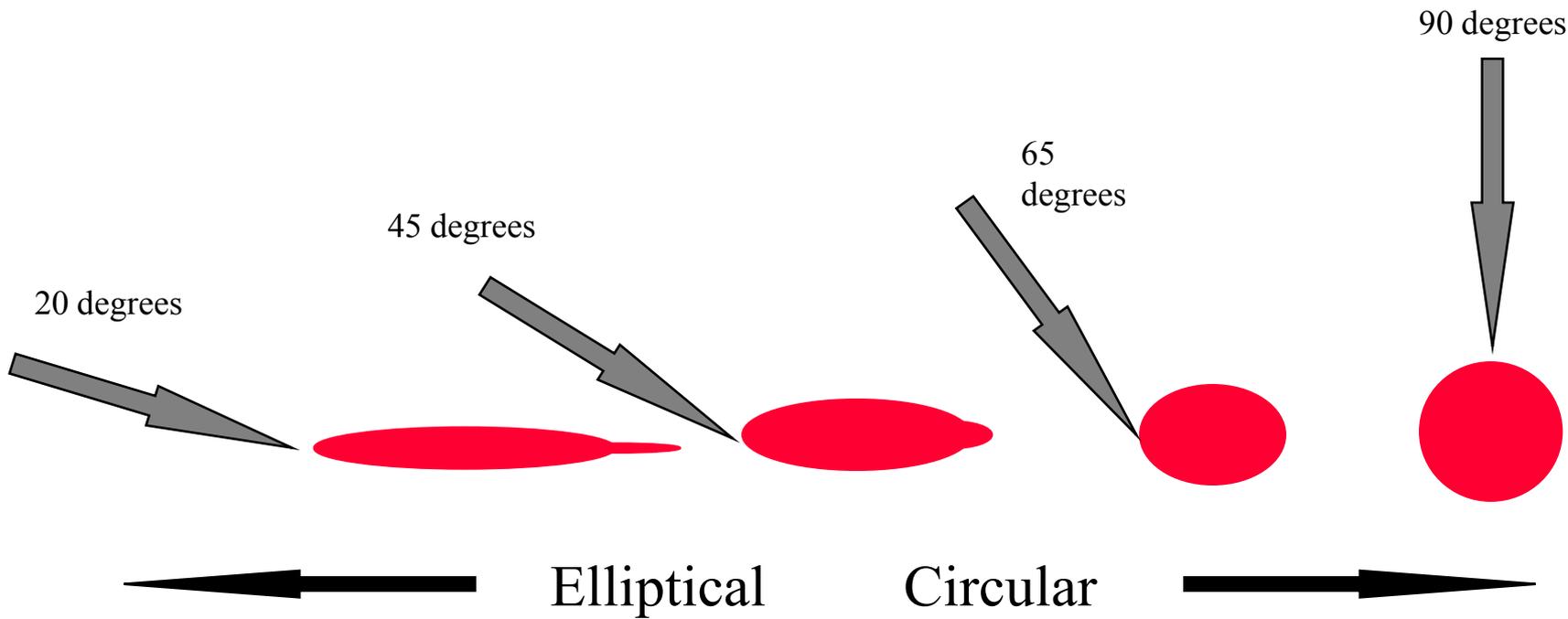
Directionality of Bloodstains

- The directionality of a bloodstain can be determined by its tail which will point in the direction of travel.





Bloodstain Shapes





The Four Basic Tenets Of Bloodstain Pattern Analysis

4/ Bloodstain patterns are predictable and reproducible.



Physics and BPA

The external forces acting on the blood drops are:

- Gravity
- Air Resistance

- The Target Surface

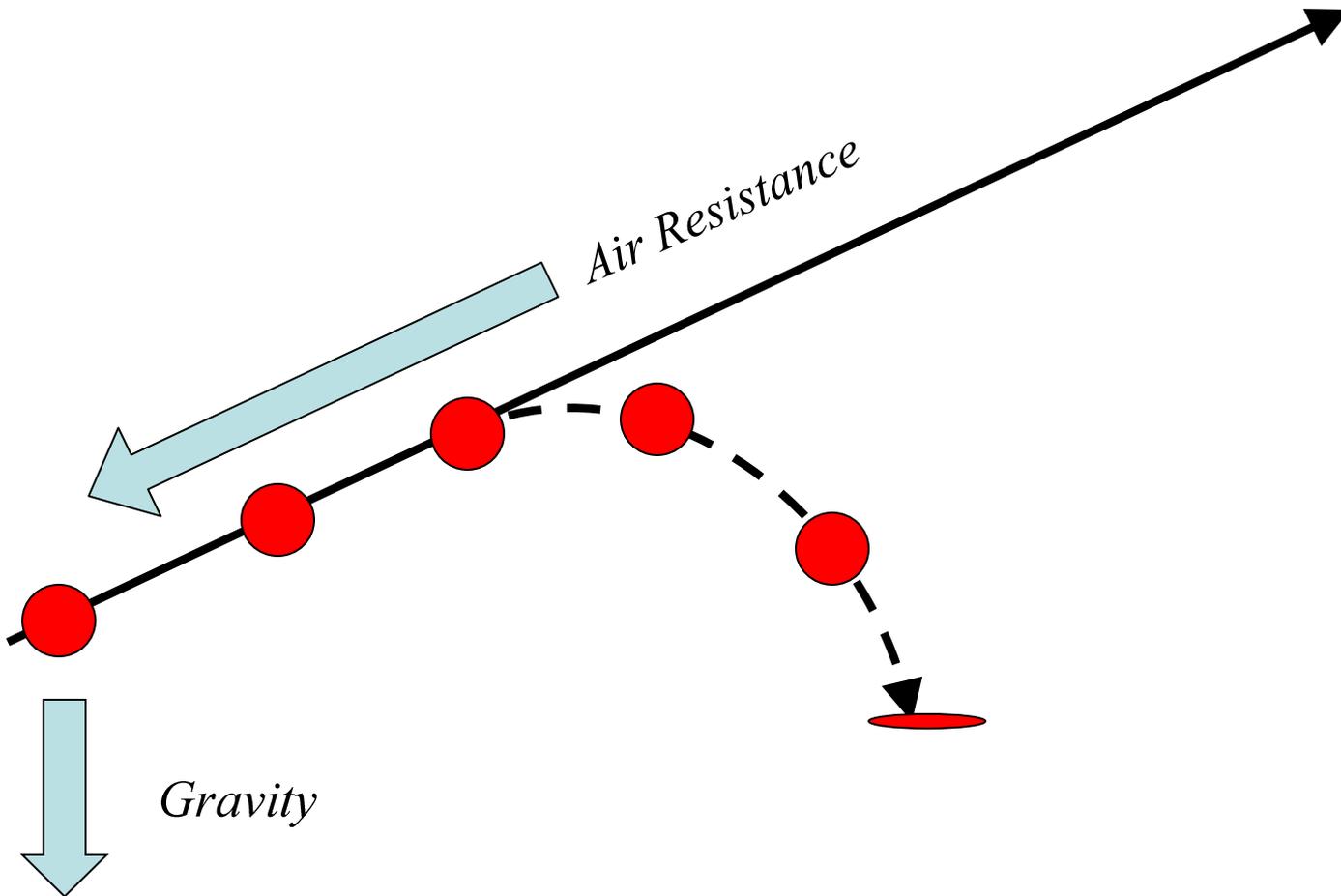




Bloodstain Pattern Analysis and Newton's First Law of Motion

Blood will behave according to the laws of physics. When it is in a liquid state, in motion, it will behave according to the laws of physical science known as ballistics. (The science of projectiles in motion.)

“An object at rest will remain at rest and an object in motion will continue in motion with a constant velocity (that is, constant speed in a straight line) unless it experiences a net external force.”





Bloodstain Pattern Analysis and Newton's Second Law of Motion

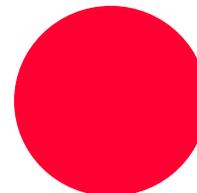
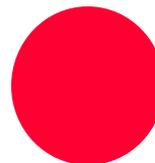
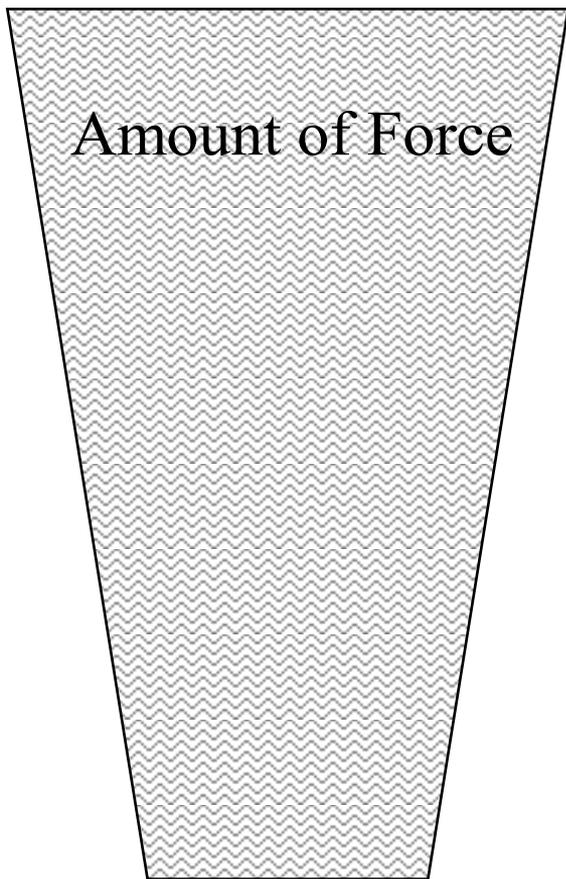
The size of a projected bloodstain has a direct relationship to the speed at which it is traveling. A small drop is moving much faster than a larger one.

“The acceleration of an object is directly proportional to the net force acting on it and inversely proportional to its mass.”



Force vs Stain Size

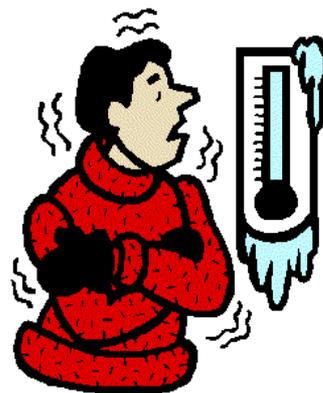
High



Low

Characteristics of Blood

- The ability of blood to reproduce specific patterns is not affected to any significant degree by age, sex, body temperature, alcoholic content, or disease.





Key Definitions

- ***Bloodstain;*** is a deposit of blood on a surface.
- ***Bloodstain Pattern;***
A grouping or distribution of bloodstains that indicates through regular or repetitive form, order or arrangement, the manner in which the pattern was deposited.



Categories of Bloodstain Patterns

- Passive
- Spatter
- Transfer



Passive Category

- *Passive bloodstains are stains that are created or formed by the force of gravity acting alone.*
- There are several patterns within this category.
 - Drip
 - Drip Trail Pattern
 - Drip Pattern
 - Splash Pattern
 - Pool Pattern
 - Saturation Pattern
 - Flow Pattern



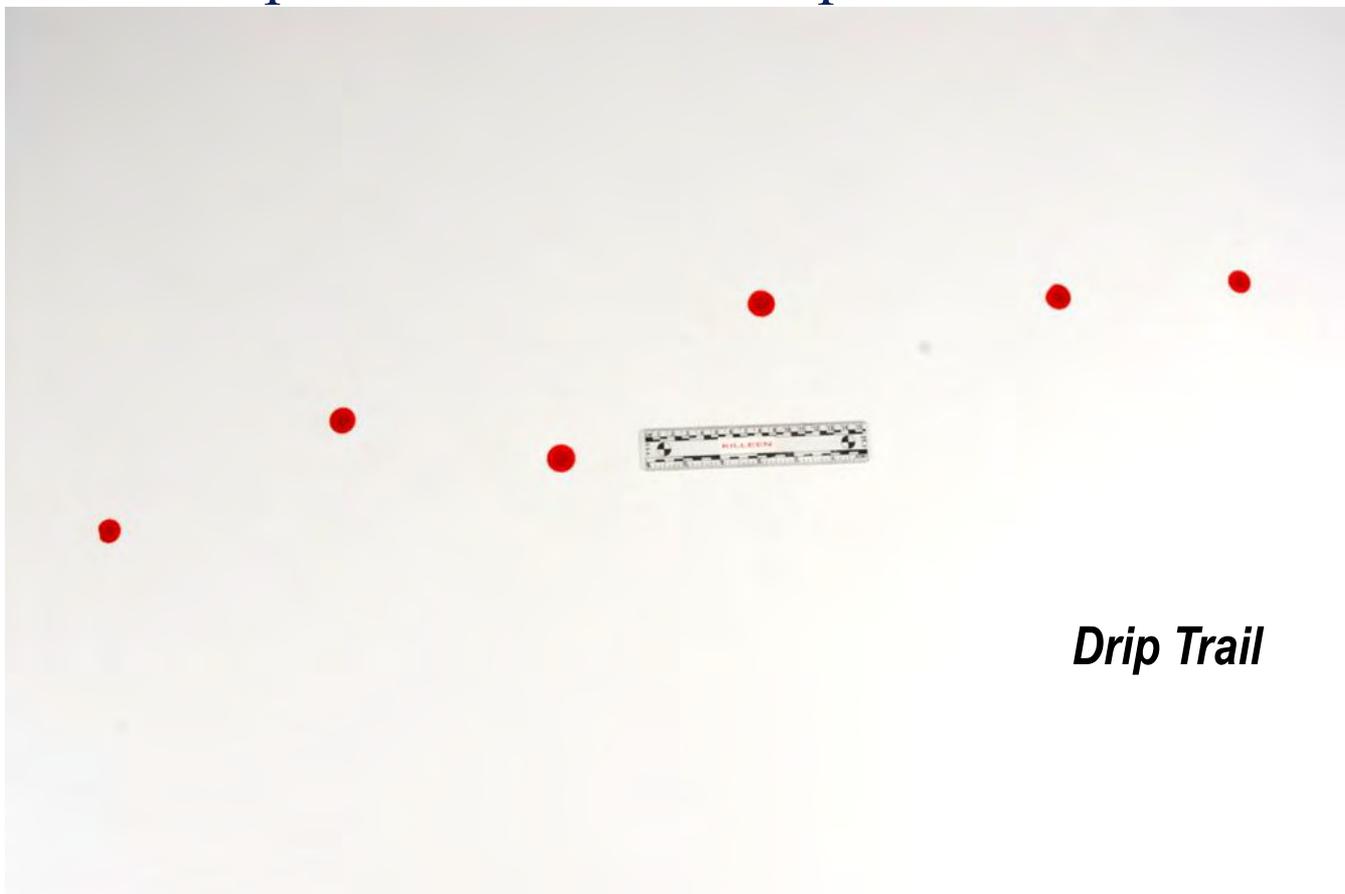
Drip Stain

- is a bloodstain resulting from a falling drop formed due to gravity.



Drip Trail

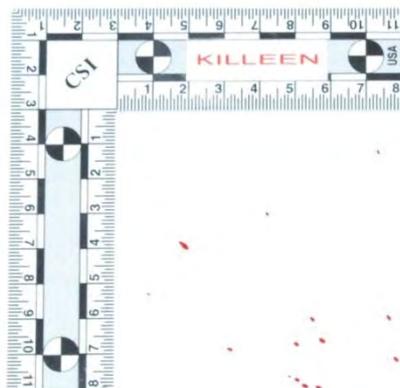
- is a bloodstain pattern resulting from the movement of a source of drip stains between two points.



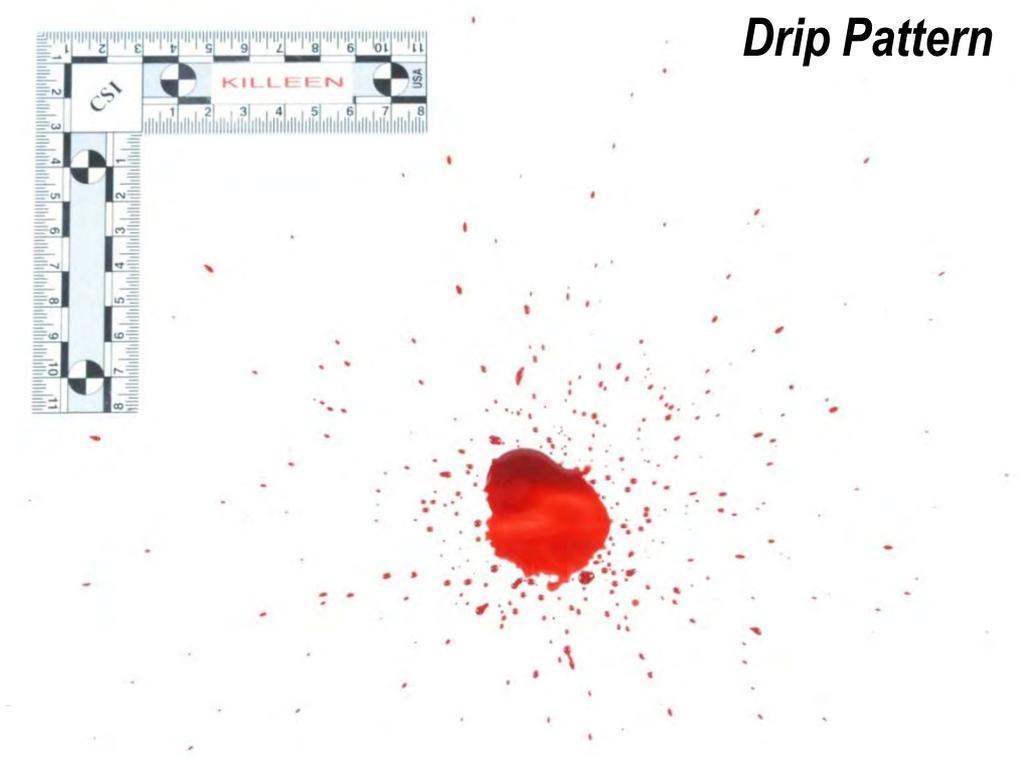
Drip Trail

Drip Pattern

- is a bloodstain pattern that results from a liquid that dripped into another liquid, at least one of which was blood.

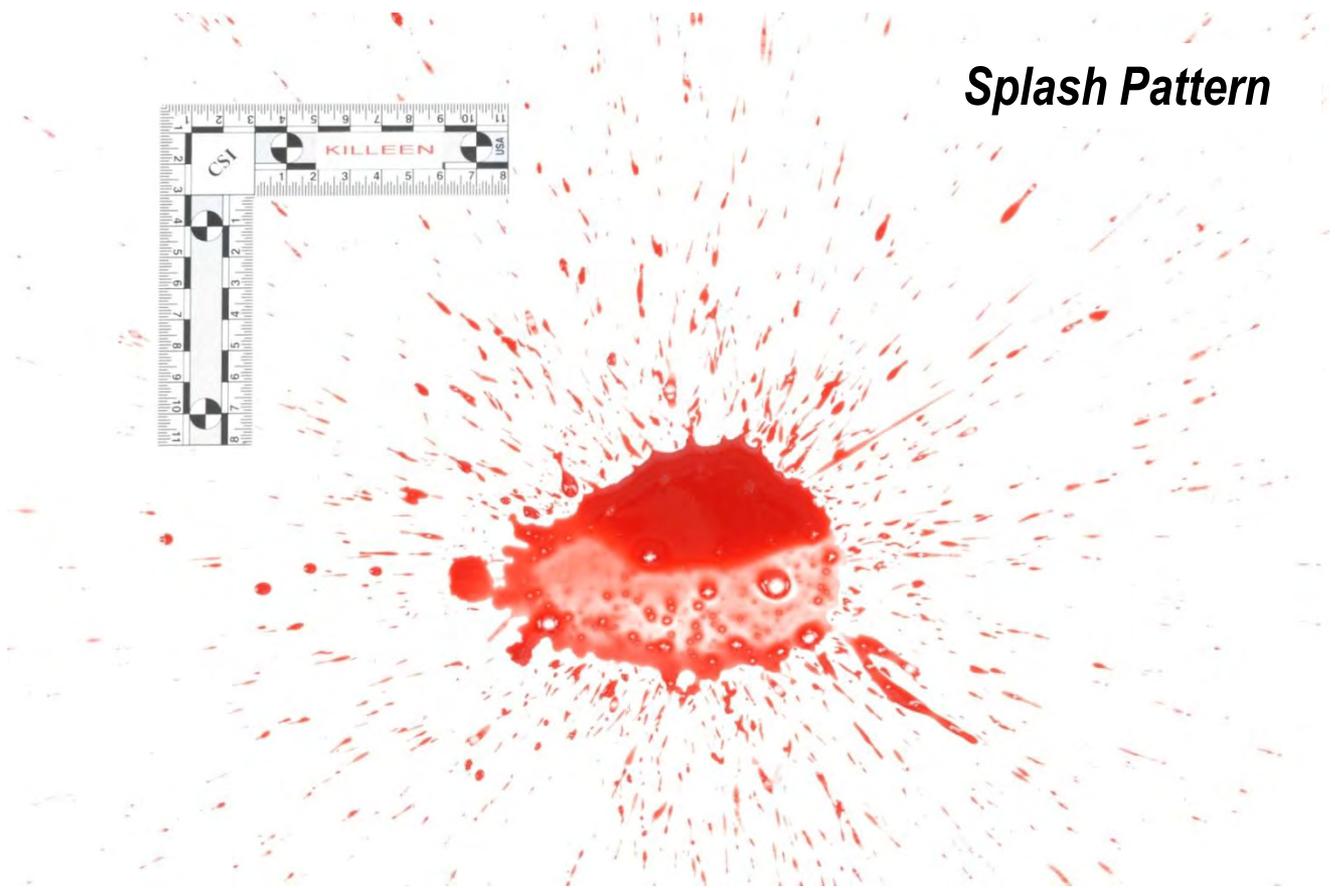


Drip Pattern



Splash Pattern

- is a bloodstain pattern resulting from a volume of liquid blood that falls or spills onto a surface.



Pool Pattern

- is a bloodstain pattern resulting from an accumulation of liquid blood on a surface.



POOL PATTERN

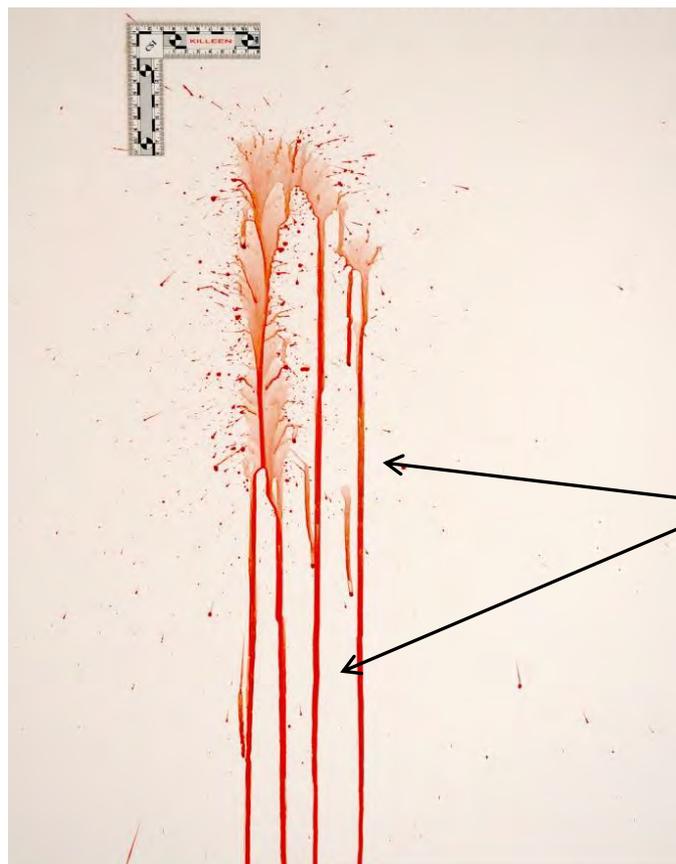
Saturation Pattern

- is a bloodstain pattern resulting from the accumulation of liquid blood in an absorbent material (e.g. fabric, dirt, etc.)



Flow Pattern

- is a bloodstain pattern resulting from the movement of a volume of blood on a surface due to gravity or movement of a target.



Flow

Transfer Category

- Transfer patterns are created when a wet bloody surface comes in contact with a second surface. In some cases, a recognizable image of all, or a portion of the original surface may be observed in the pattern.*



Transfer/Contact Pattern

Swipe Pattern

Wipe Pattern

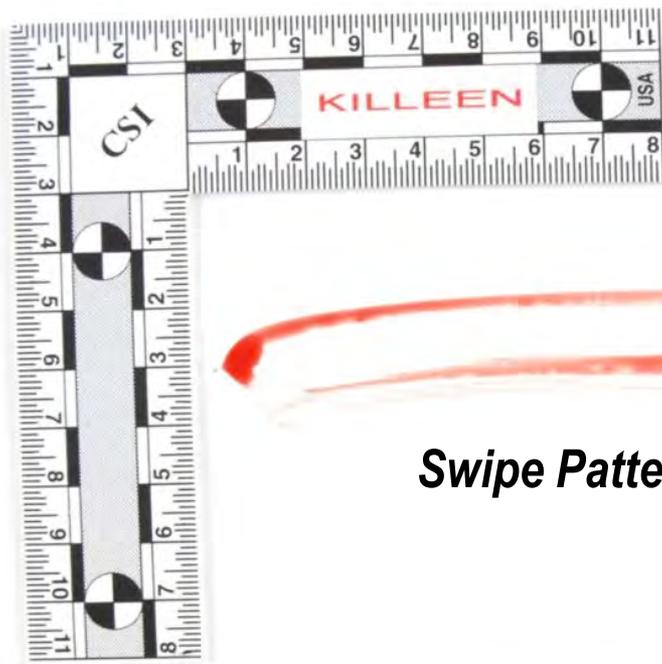
Transfer/Contact Pattern

- is a bloodstain pattern resulting from contact between a blood bearing surface and another surface.



Swipe Pattern

- is a bloodstain pattern resulting from the transfer of blood from a blood-bearing surface onto another surface, with characteristics that indicate relative motion between the two surfaces.



Swipe Pattern

Spatter Category

- *bloodstains resulting from blood drops dispersed through the air due to an external force being applied to a source of liquid blood.*
 - Impact Pattern
 - Mist Pattern
 - Expiration Pattern
 - Cast-Off Pattern &
 - Cessation Cast-Off Pattern
 - Projected



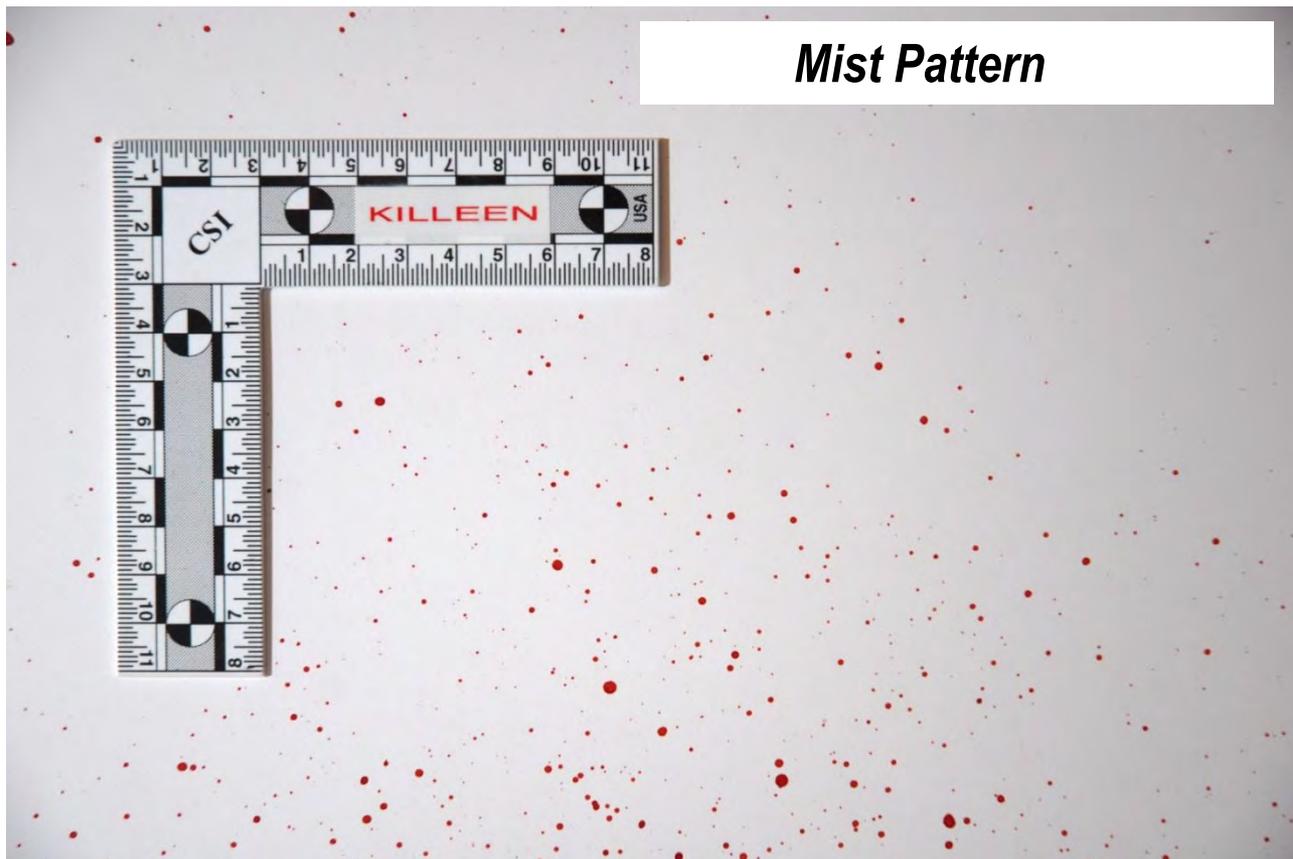
Impact Pattern

- is a bloodstain pattern resulting from an object striking liquid blood.



Mist Pattern

- is a bloodstain pattern resulting from blood reduced to a spray of micro-drops as a result of the force applied.



Expiration Pattern

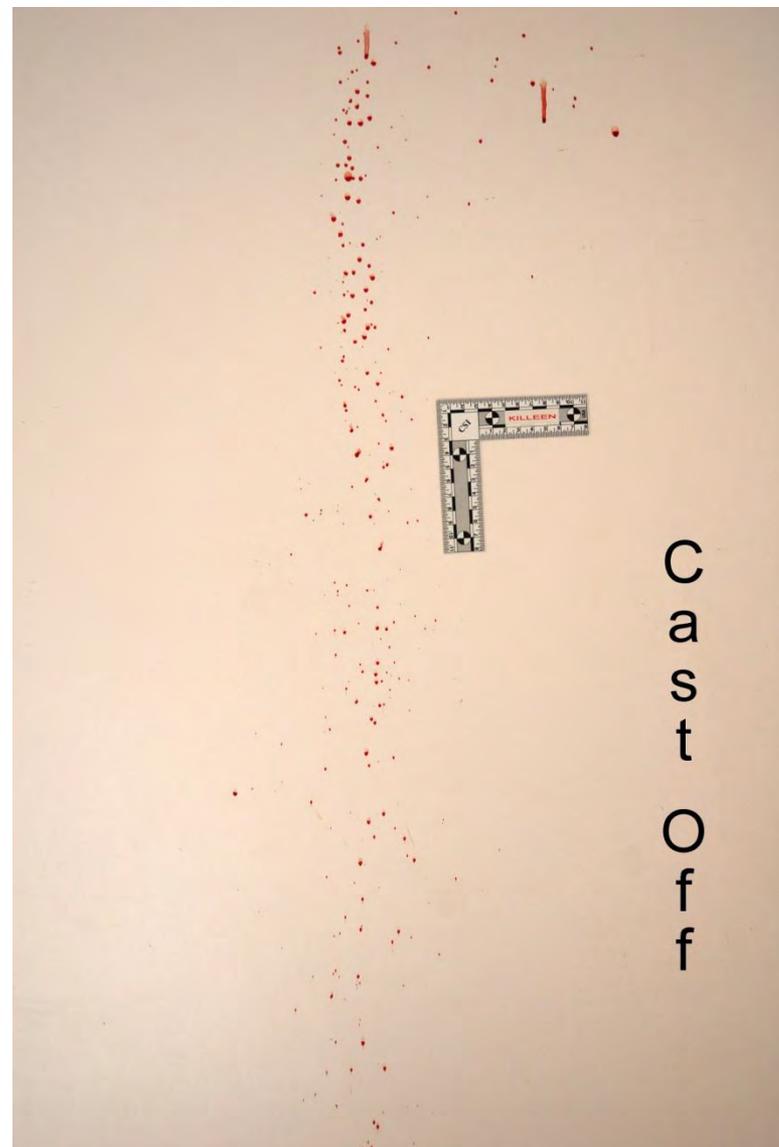
- is a bloodstain pattern resulting from blood forced by airflow out of the nose, mouth or a wound.



Expiration Pattern

Cast-Off Pattern

- is a bloodstain pattern resulting from drops released from an object due to its motion.



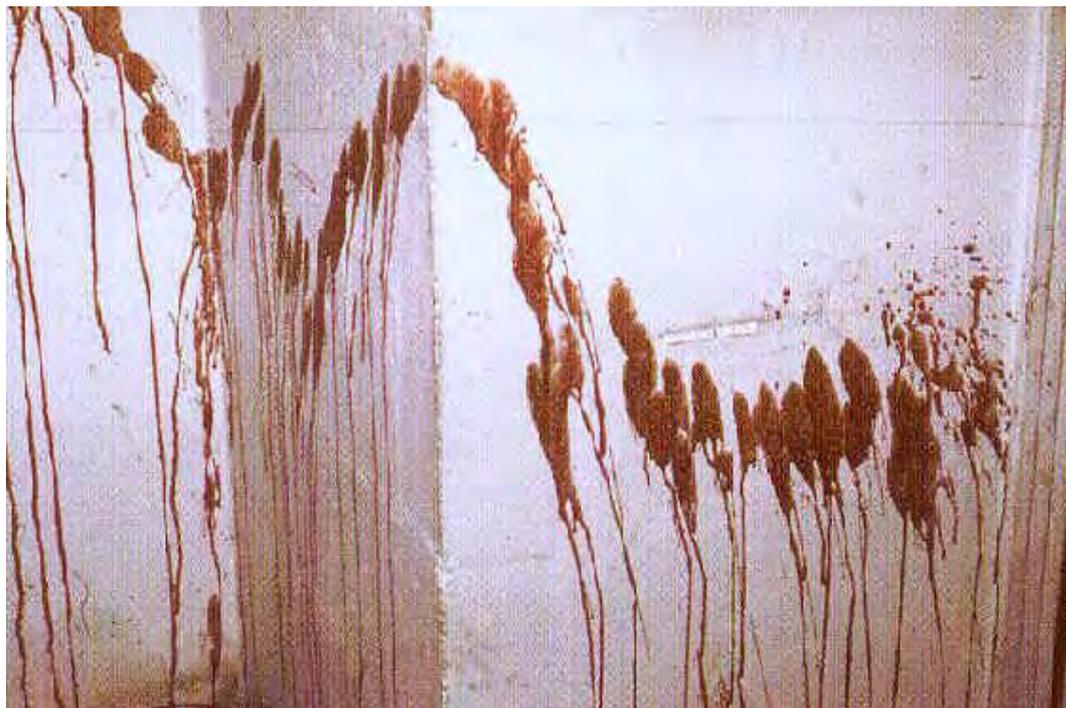
Cessation Cast-Off Pattern

- is a bloodstain pattern resulting from blood drops released from an object due to its rapid deceleration.



Projected Pattern

- is a bloodstain pattern resulting from the ejection of a volume of blood under pressure.





Another example of projected blood -



“Just a flesh wound!”

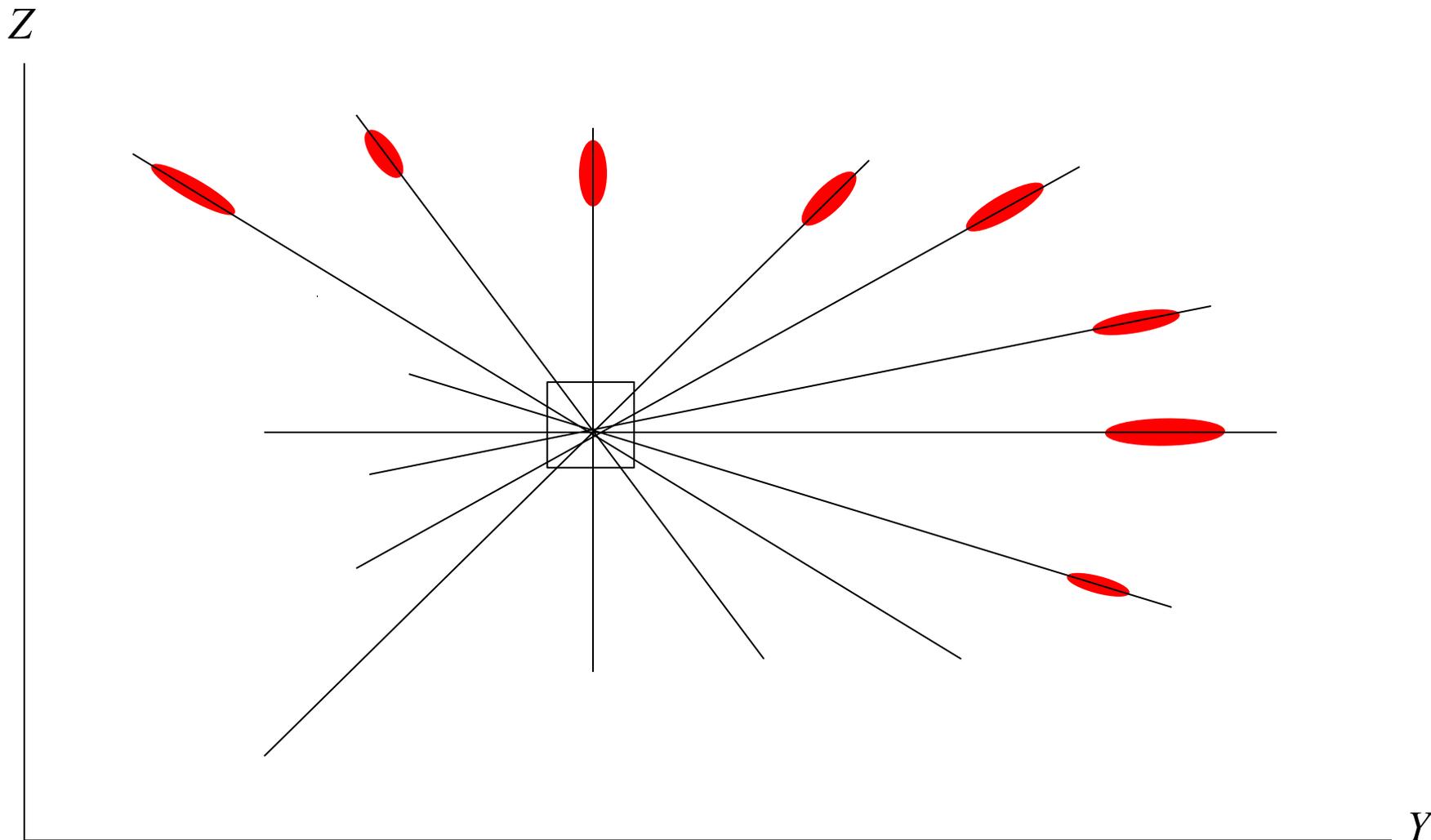


Area of Convergence

- The area containing the intersections generated by lines drawn through the long axis of individual stains that indicates in two dimensions the location of the blood source.



Area of Convergence



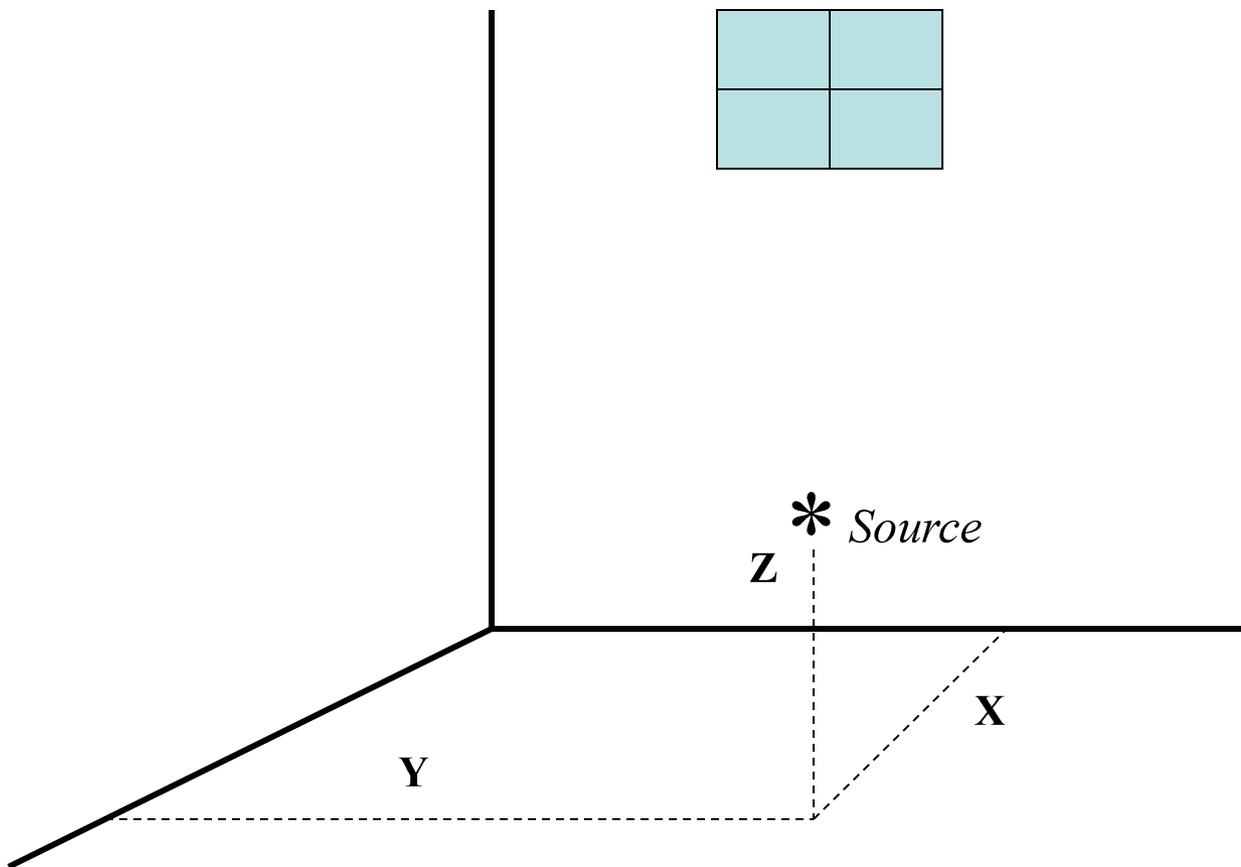


Area of Origin

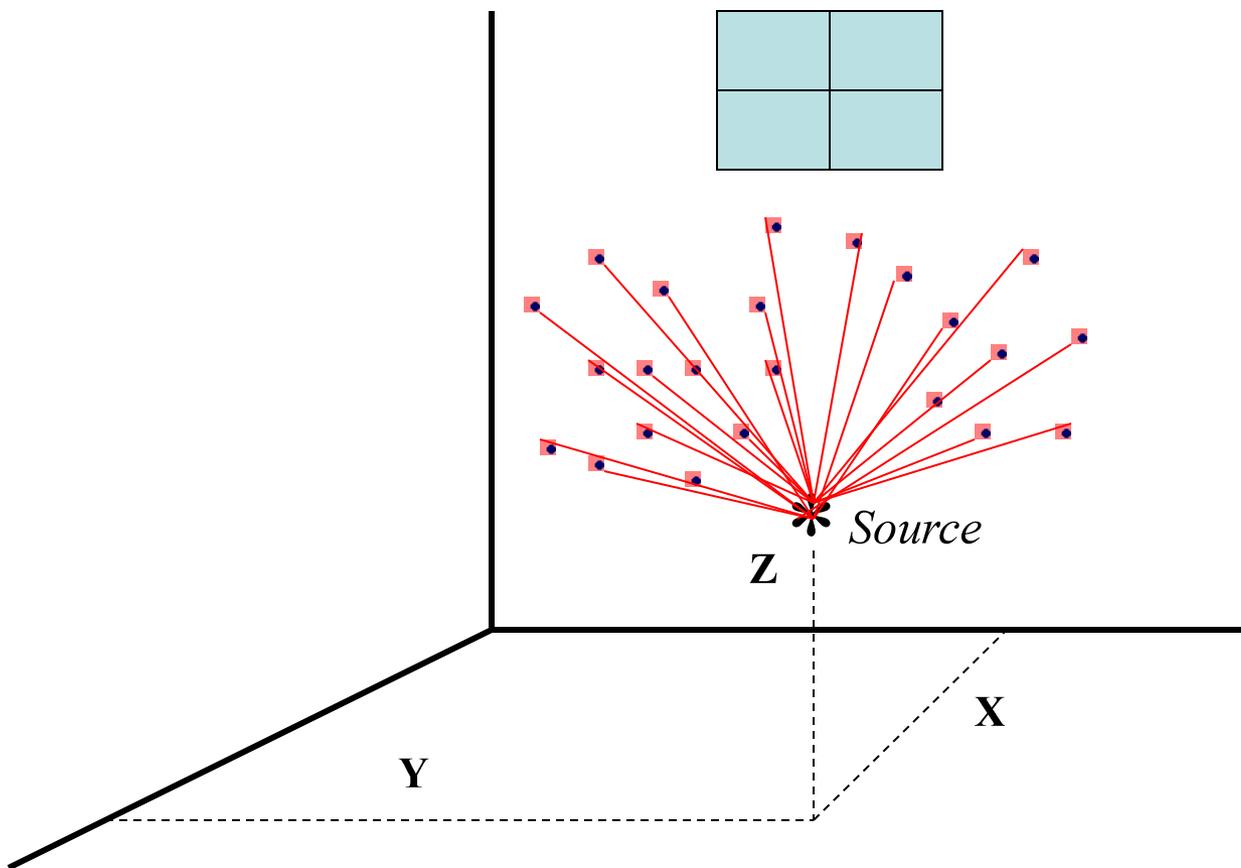
- The three-dimensional location from which spatter originated.



Area of Origin



Area of Origin





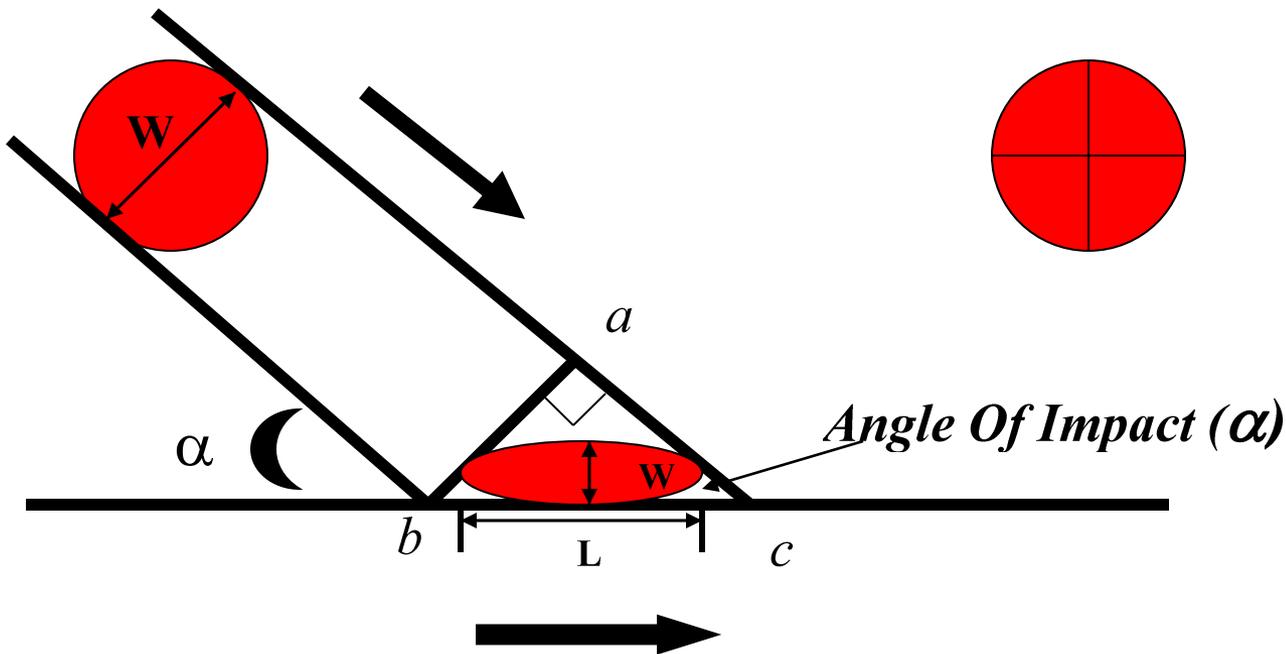
Calculation of the Area of Origin

The area of origin may be determined in a number of different ways;

- Mathematically (Tangent Method)
- Stringing Method
- Use of Computer Software

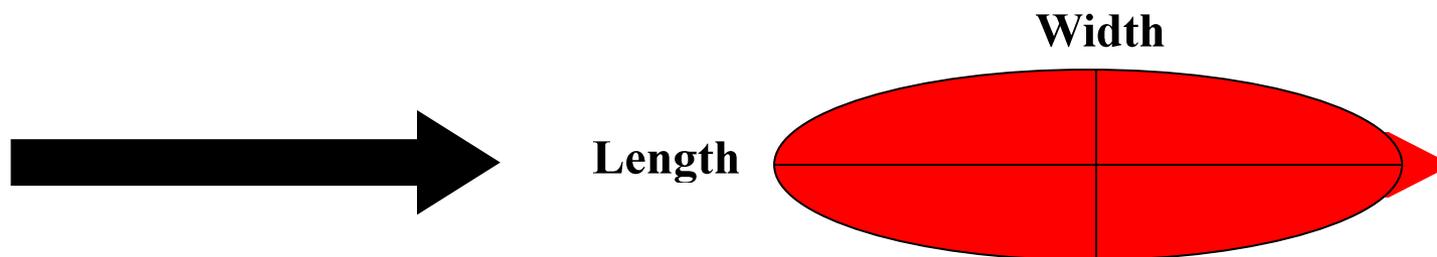
Angle of Impact

- The angle of impact is the acute angle formed between the direction of a blood drop and the plane of the surface it strikes.



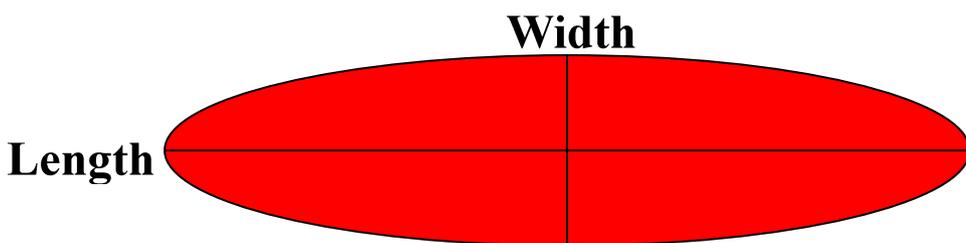
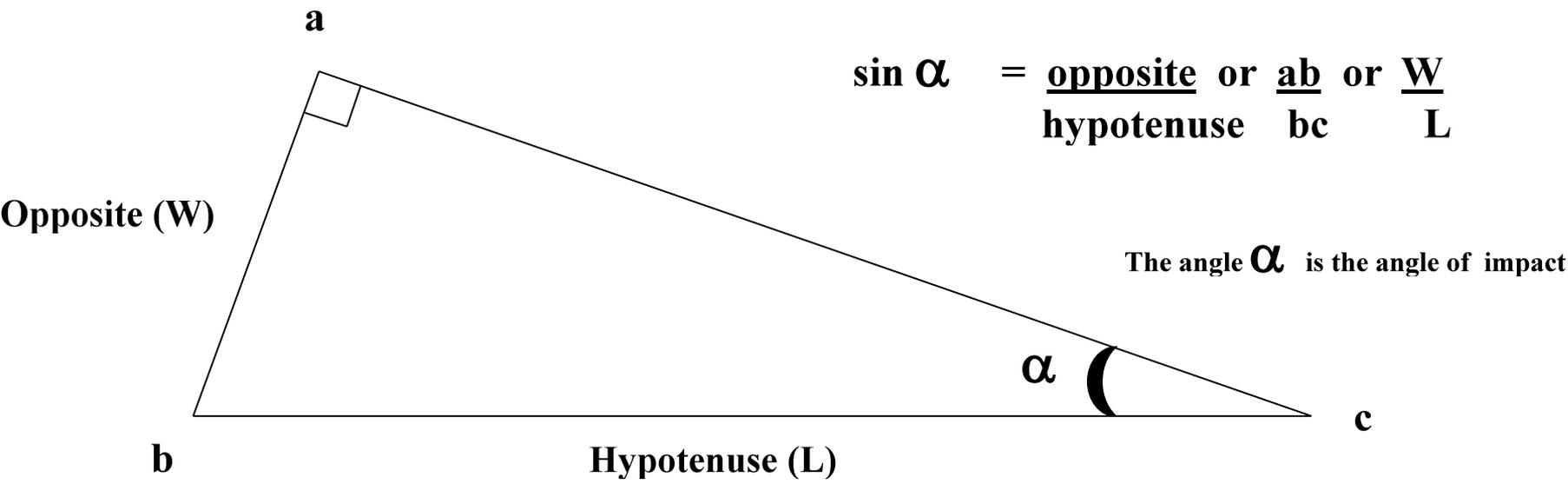
Determination of the Impact Angle

- The impact angle is determined from the ratio of the width to the length of the stain.

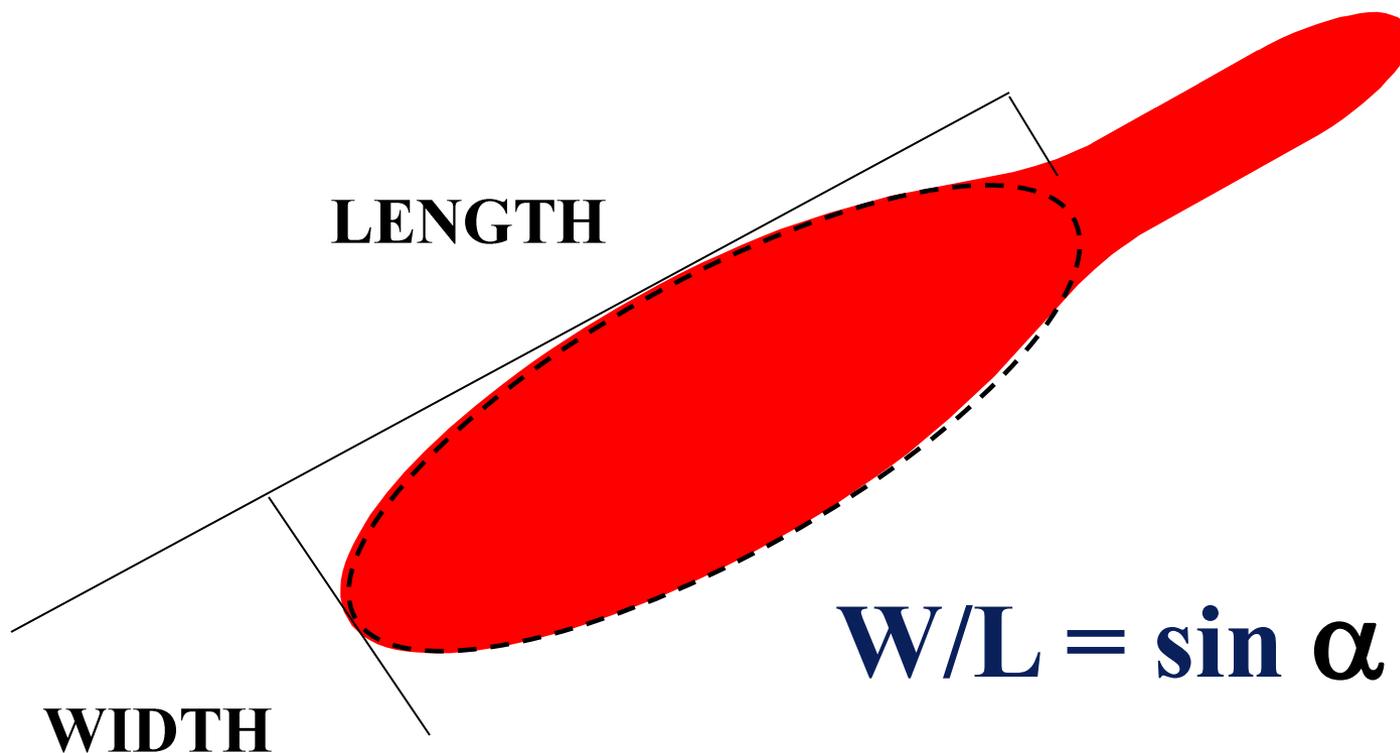


** Balthazard et al "Research On Blood Spatter" Paris 1939*

Determination of the Impact Angle



Determination of the Impact Angle

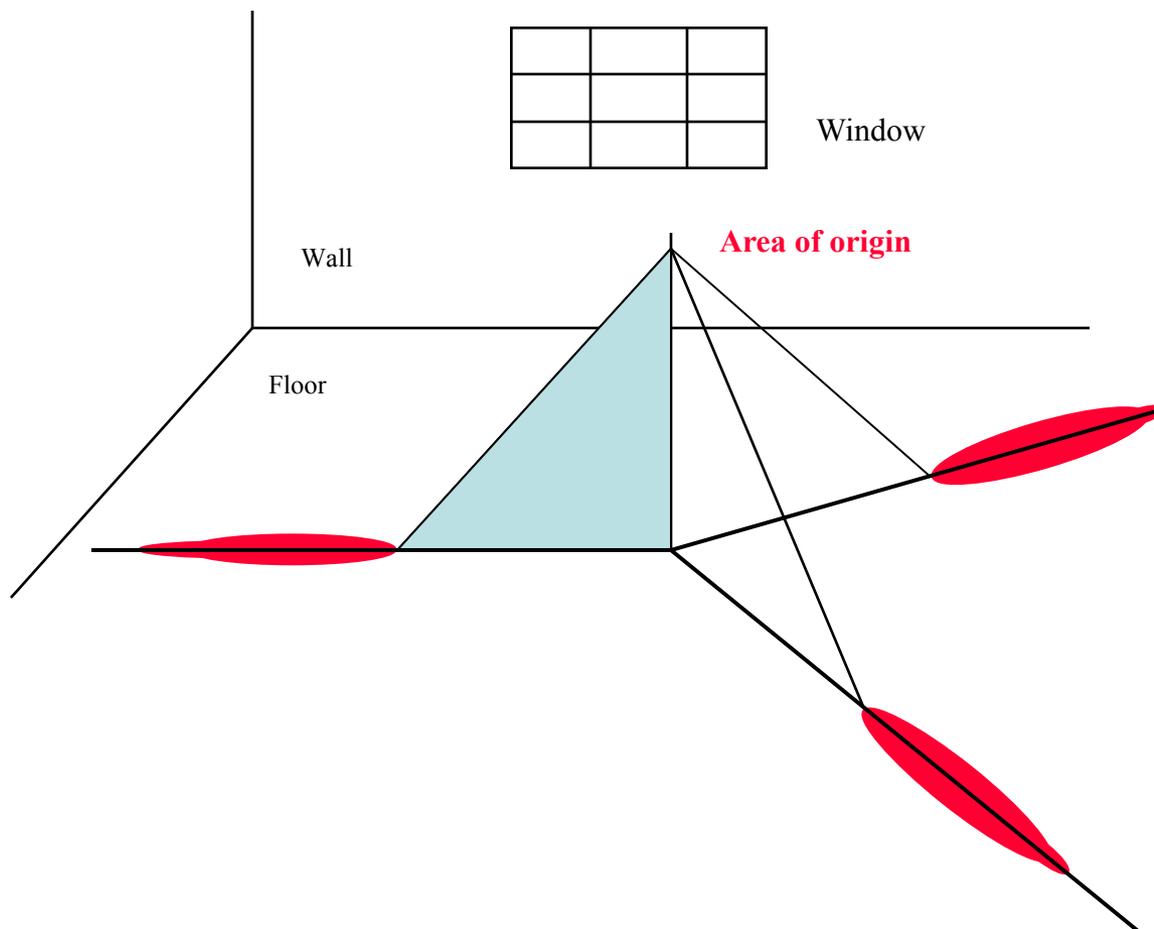


$$W/L = \sin \alpha$$

$$\arcsin (W/L) = \alpha$$

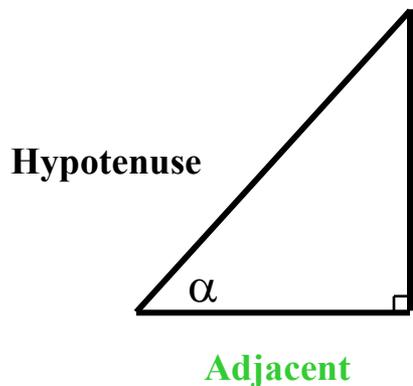


Area of Origin





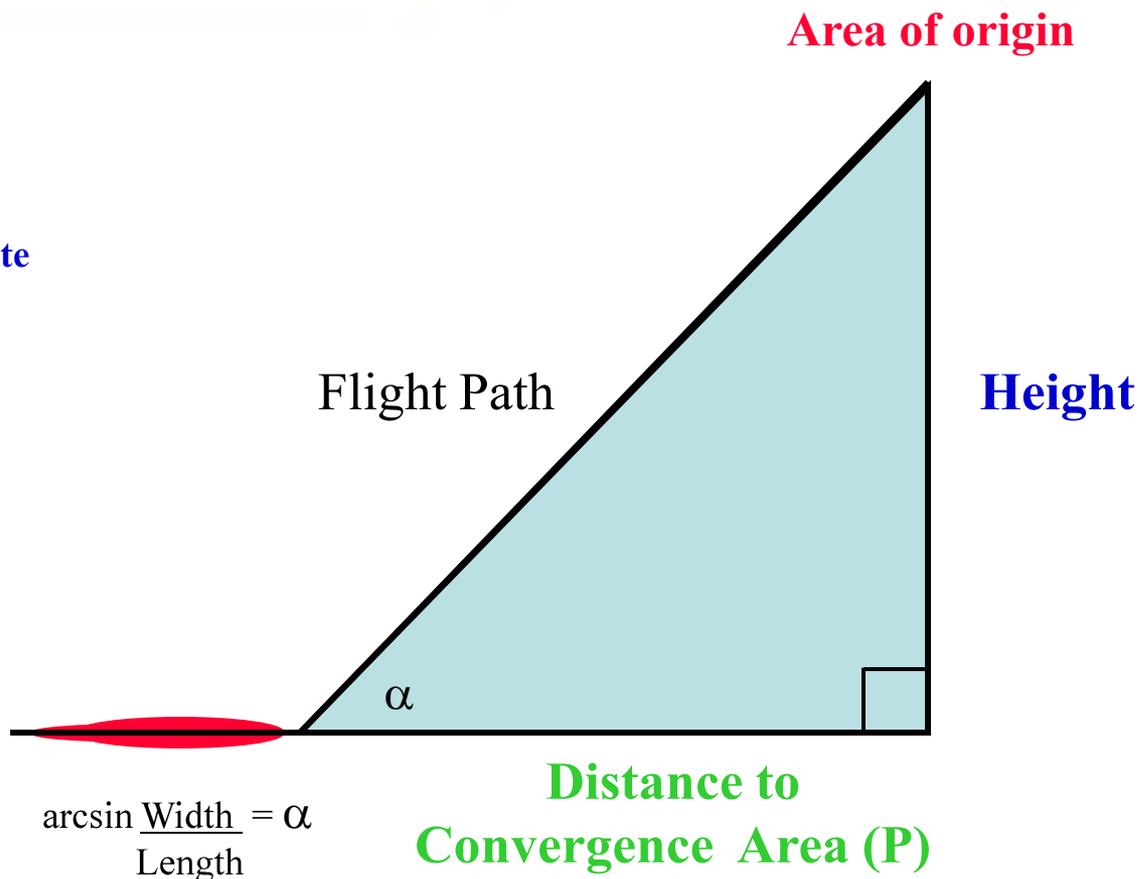
Right Angle Triangles



$$\tan \alpha = \frac{\text{Opposite}}{\text{Adjacent}}$$

$$\tan \alpha = \frac{\text{Height}}{\text{P}}$$

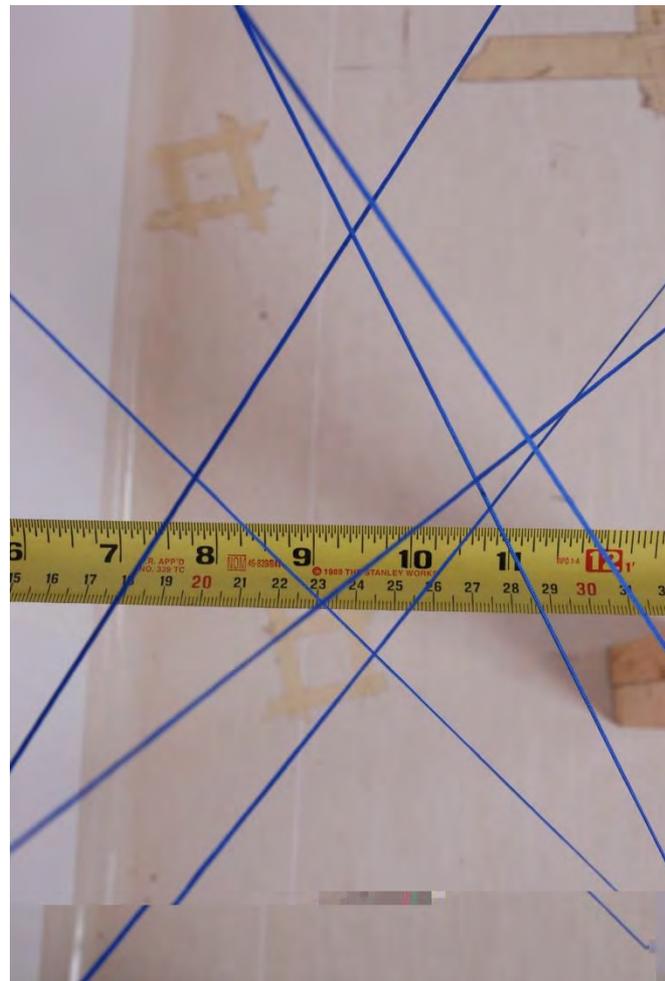
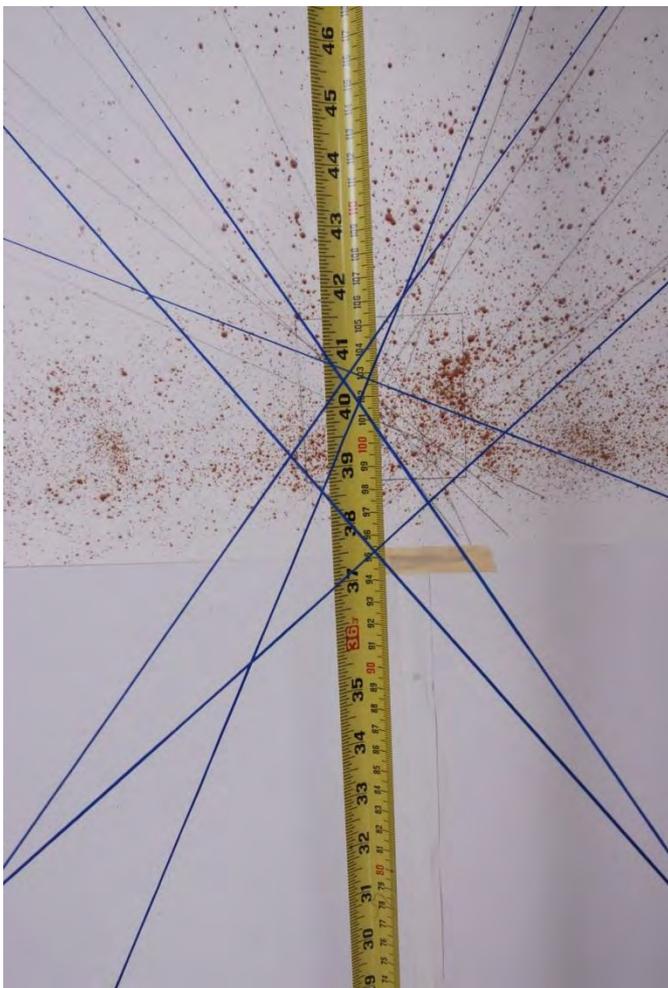
$$\text{Height} = \tan \alpha \times \text{P}$$



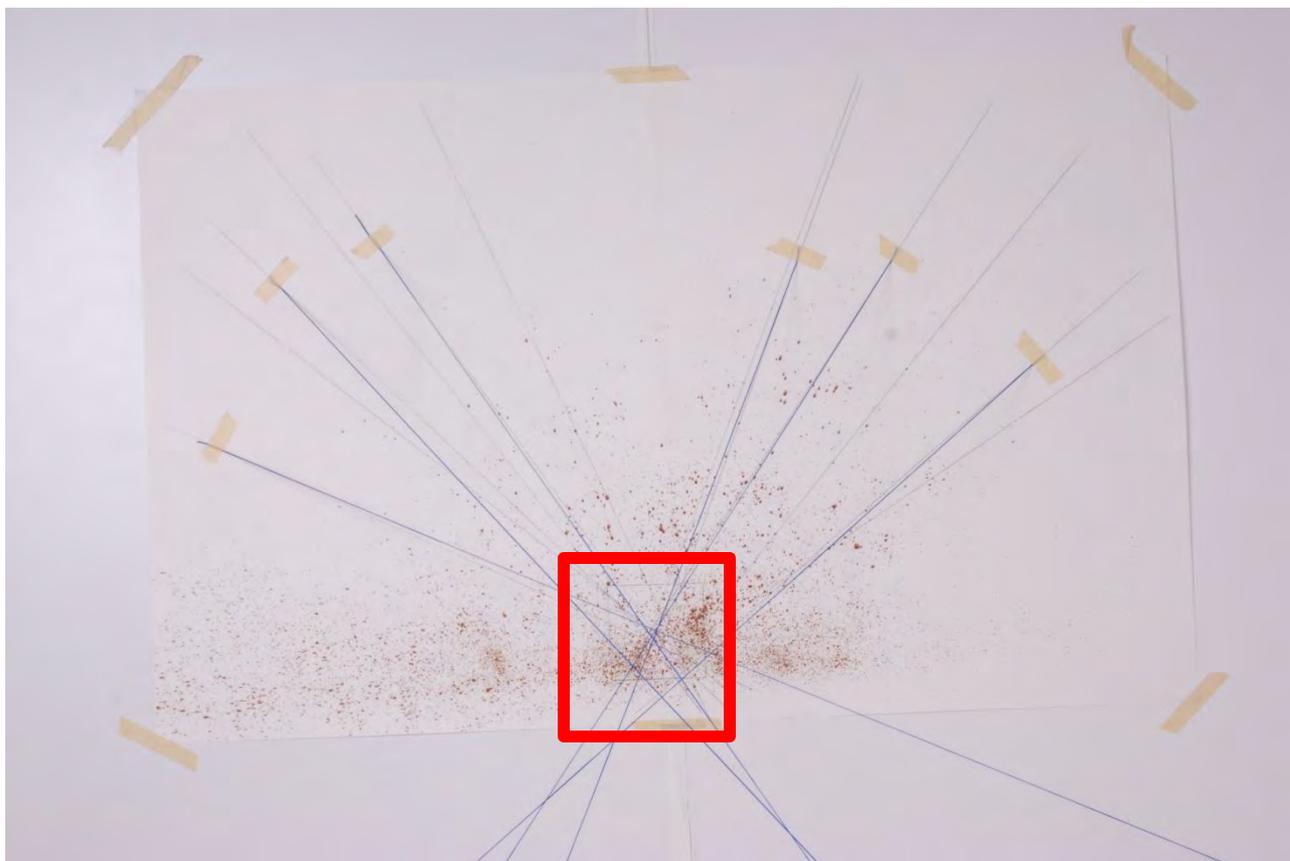
Stringing Method



Stringing Method



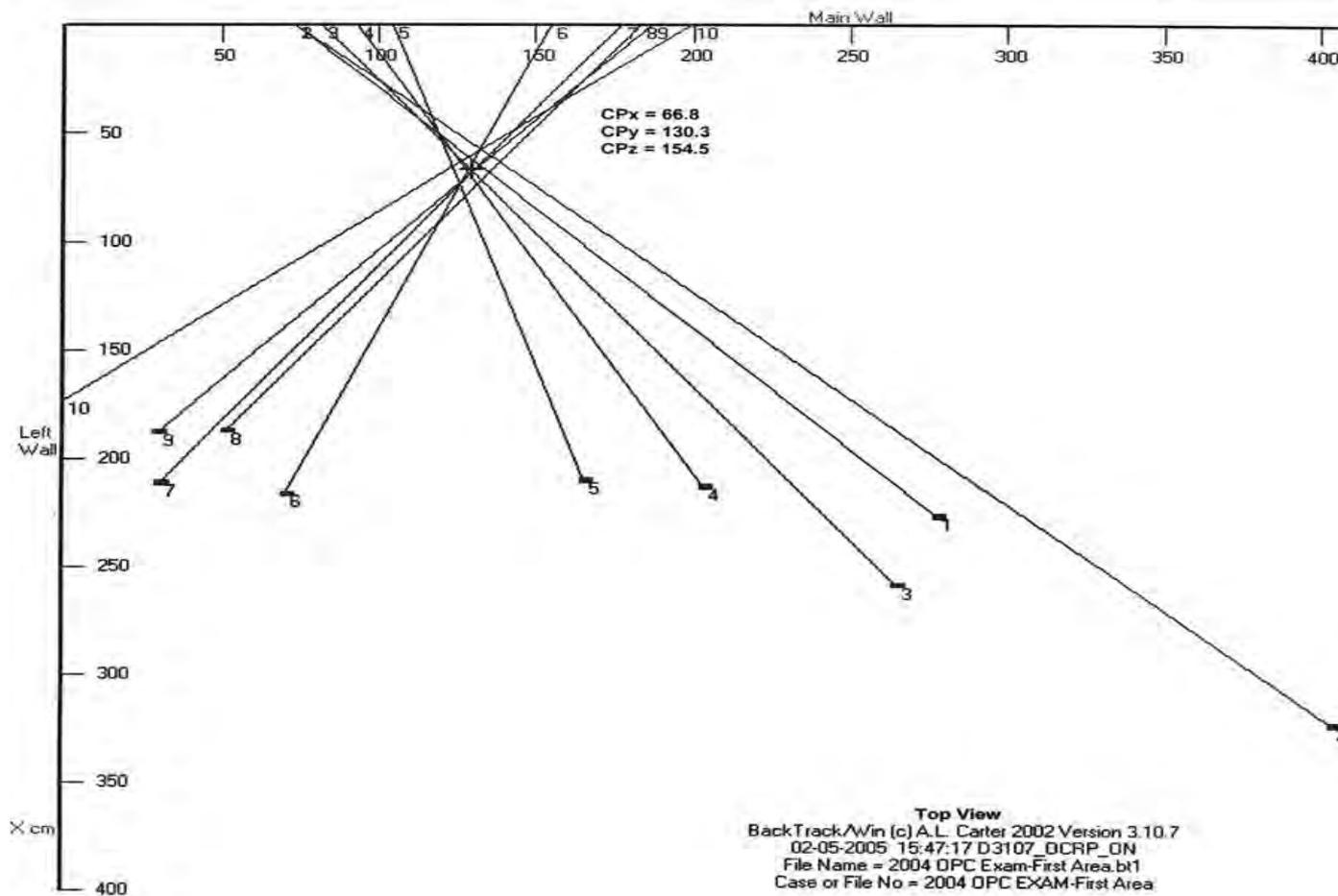
Stringing







Computer Program - BackTrack



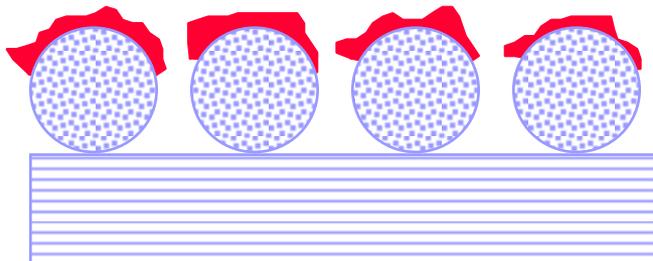
Forensic Computing Of Ottawa Inc
Dr. Fred Carter--BackTrack Software For Directional Analysis Of Bloodstain Patterns At Crime Scenes

Bloodstain Pattern Analysis and Clothing



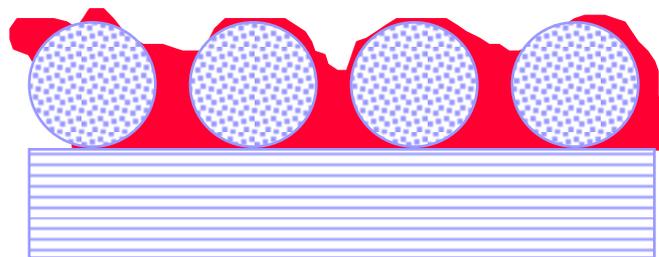
Transfer vs. Spatter Stains on Clothing

Transfer Stain



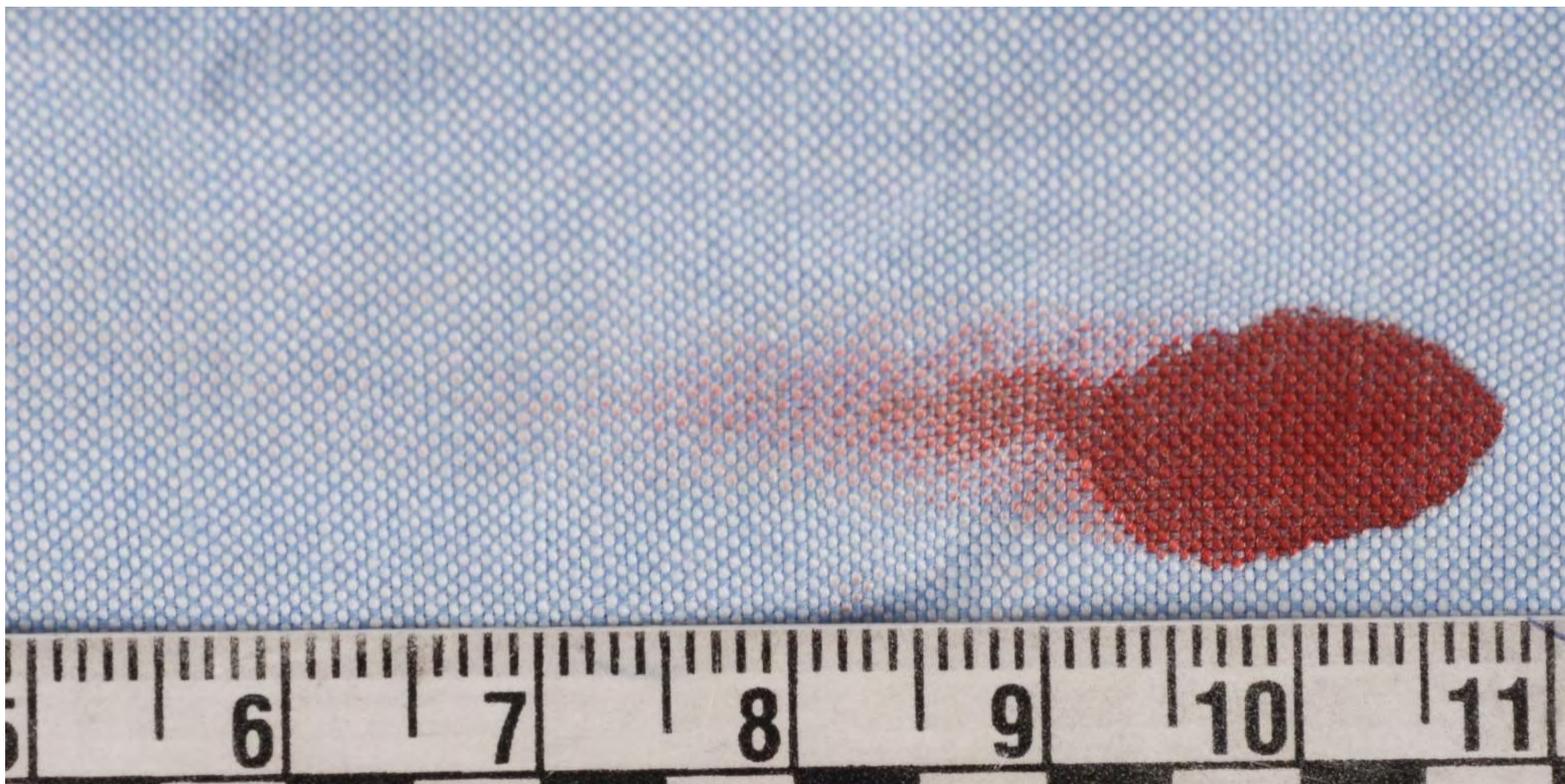
Cross section of a piece of fabric

Spatter Stain

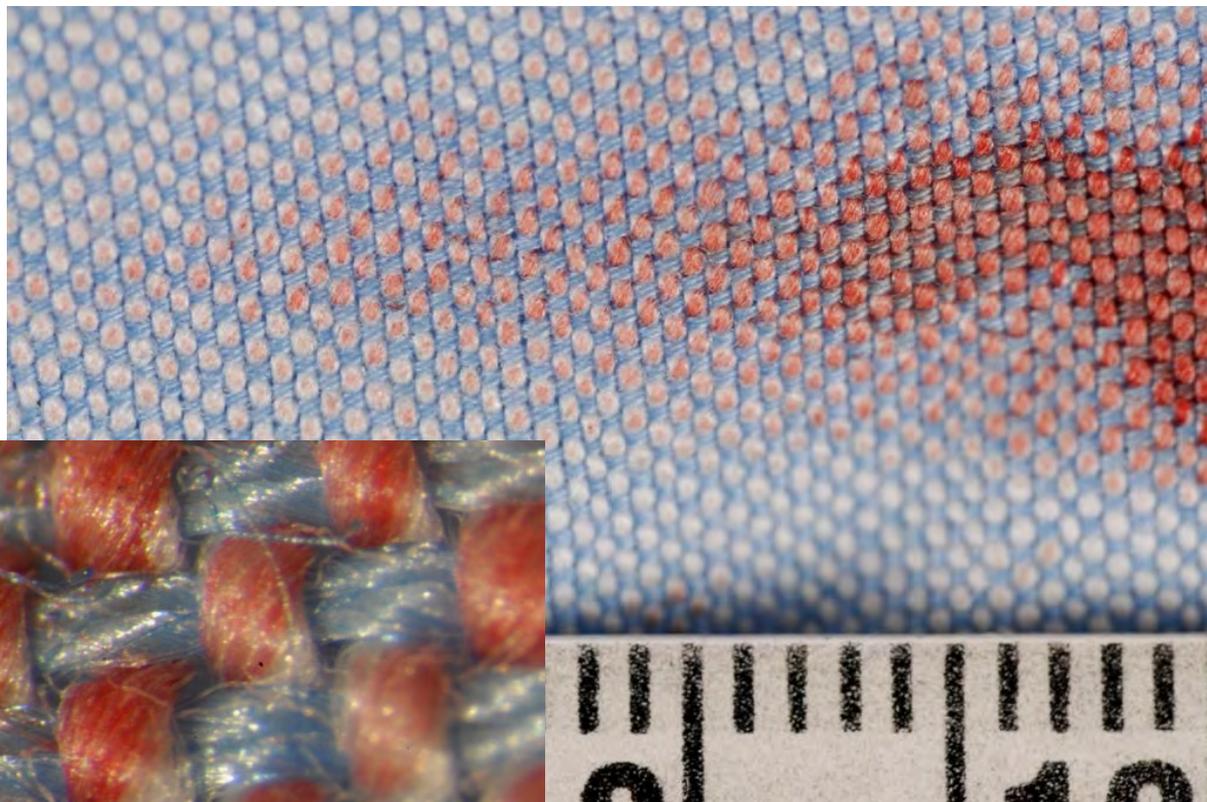


Cross section of a piece of fabric

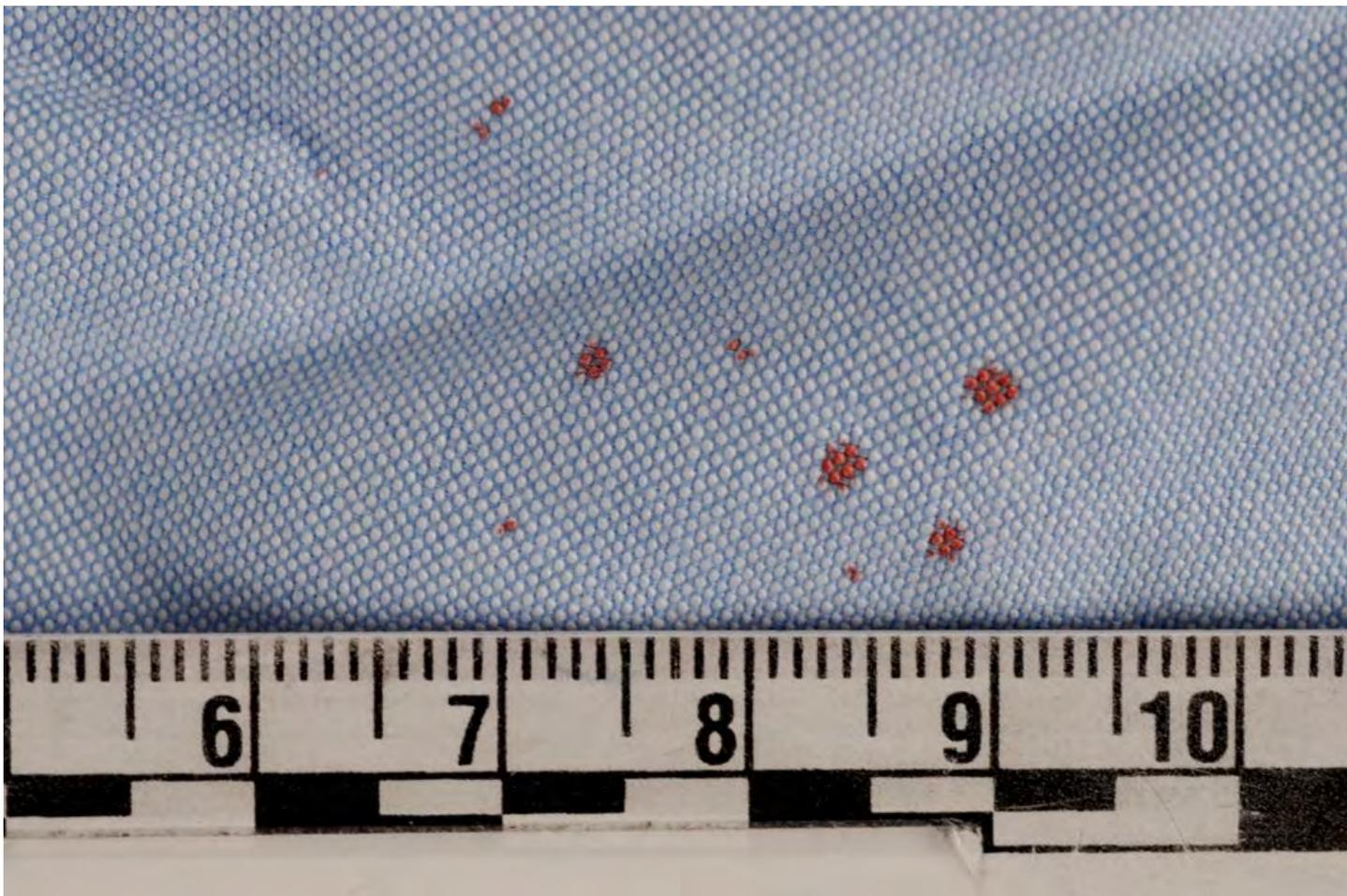
Transfer Stains on Clothing



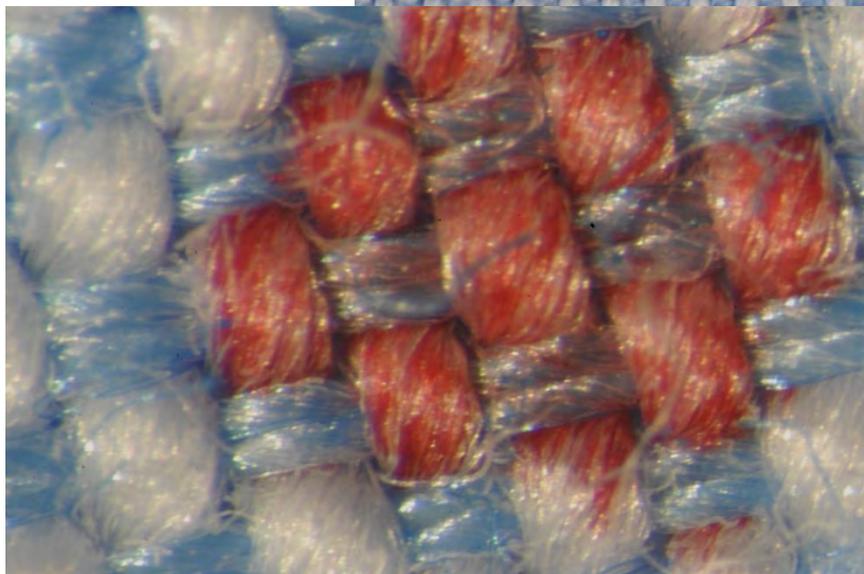
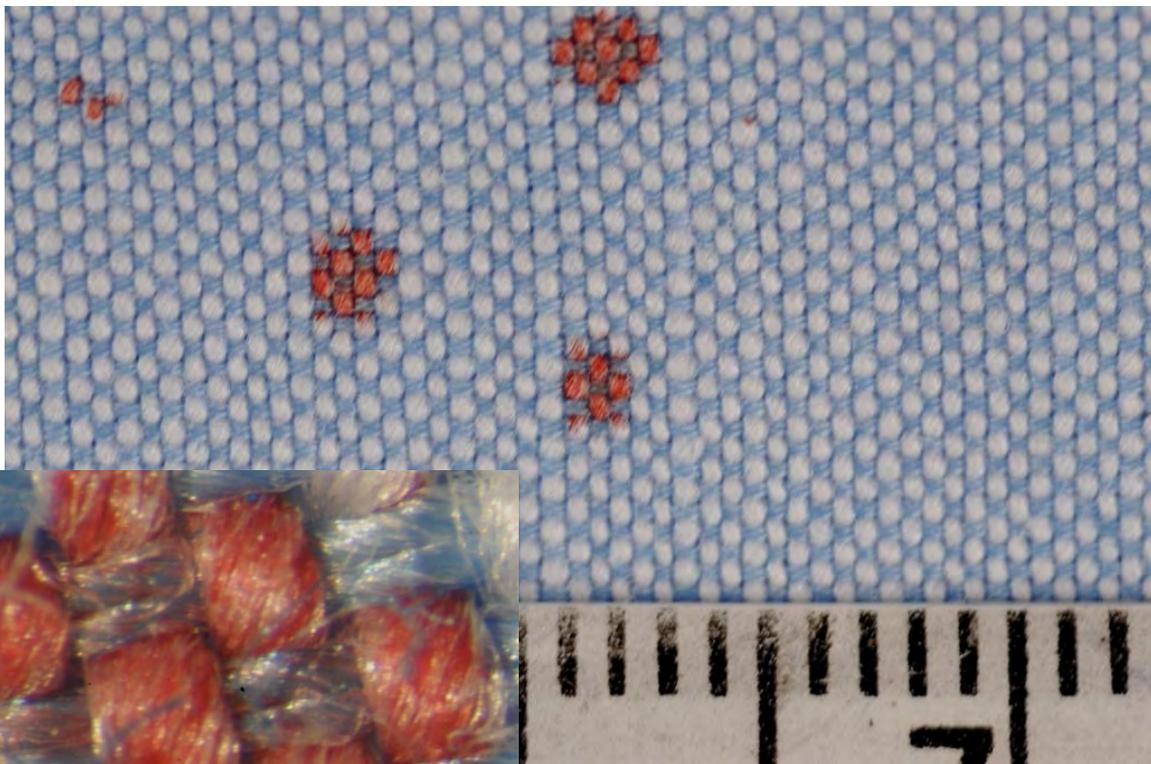
Transfer Stains on Clothing



Spatter Stains on Clothing



Spatter Stains on Clothing



Presumptive Tests for Blood

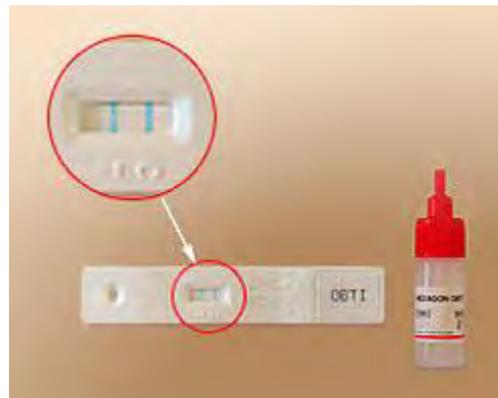
Hemastix;

- presumptive for blood
- reacts to hemoglobin in blood
- **green reaction on test strip**
- can get false positives; rusty metals, saliva, grass stains, and some fruit juices
- requires confirmatory test by lab



Hexagon Obti;

- presumptive for human & primate blood
- reacts to hemoglobin
- two lines appear on indicator
- as little as only 500 red blood cells required
- requires confirmatory test by lab





Chemical Enhancement/Detection

- There are several chemicals used to either enhance bloodstain patterns, or detect areas of a possible blood clean-up.
- Common techniques; Luminol, Leucomalachite Green (LMG), Amido Black, Hungarian Red, or Flourescein.
- Each reagent has its advantages and disadvantages and the use has to be determined on a case by case basis.
- **It is important to remember that the techniques used for the detection of blood are presumptive tests only, the actual presence of blood must be confirmed through DNA testing.**

Luminol

- Water-based, easy to use, low toxicity make it a commonly used chemical
- Reacts to the hemoglobin in blood, iron specifically
- Luminol is a presumptive test for blood only. A positive reaction is signified by the production of a sustained bluish-green luminescence.
- In a darkened room the reaction can be photographed.



Luminol



Luminol



Luminol photos courtesy of the Police Academy of the Netherlands



BPA and Case Law in Canada

- **R. vs. Sparrow, 1979** – Admissibility of BPA
- **R. vs. Luciano, 2004** – Qualification of Expert (it's not junk science)
- **R. vs. O'Grady, 1999** – Qualification of Expert – (Acquired Special or Peculiar Knowledge via Study/Experience)
- **R. vs. Giesbrecht, 2006** – Issue of Identity
- **R. vs. Flegel, 2005** – Defence of Provocation
- **R. vs. Teske, 2005** – Inferring Intent of the Accused



Resources

- www.iabpa.org (International Association of Bloodstain Pattern Analysts)
- www.swgstain.org (Scientific Working Group for Bloodstain Pattern Analysis)
- killeenjim@ottawapolice.ca



Classic Texts

- MacDonell- “Bloodstain Pattern Interpretation” (1983) and “Bloodstain Patterns” (1993)
- Eckert & James- “Interpretation of Bloodstain Evidence at Crime Scenes” (1989) A second edition was released in 1998.
- Bevel & Gardner- “Bloodstain Pattern Analysis-Theory & Practice-A Laboratory Manual” (1990) and “Bloodstain Pattern Analysis With an Introduction to Crime Scene Reconstruction” (1997) A second edition was released in 2002.
- “Scientific And Legal Applications of Bloodstain Pattern Interpretation” (1999) Edited by Stuart James
- James/Kish & Sutton- “Principles of Bloodstain Pattern Analysis” (2005)



Any questions?

