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A comparative study on variations in bloodstain patterns due to change in surface angles-using blood from four common animal species

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Abstract
In crime scene investigations, particularly in cases of homicide, the pattern or the shape of bloodstains at the crime scene is of crucial importance. Bloodstain pattern defines the facts surrounding some incident that is in question. The shape and size of the bloodstain pattern is helpful in determining the area of convergence, point of origin, the direction of the blood droplet at the time of impact, the angle of impact, the nature of force involved, direction from which force was applied, the nature of the object used and the relative positions of the suspect, victim and other related objects during the incident. When the examination of bloodstains is done efficiently and carefully and if all possibilities are exhausted, shape, location and site of bloodstain can give important details about the circumstances of the crime. Keeping the importance of physical properties of blood in mind the present study is carried out with the aim to study the inter species variations in the patterns formed by the blood of four commonly found animal species; pig (*Sus scrofa domestica*), goat (C*apra ibex*), human (*Homo sapien sapiens)* and chicken (*Gallus gallus*), and red ink as control. In the present study, the variations in bloodstain pattern of four common animal species, when blood is allowed to fall from a fixed height at various surface angles are demonstrated.

Keywords: Bloodstain pattern, homicide, point of origin, area of convergence, interspecies

1. Introduction

Blood is one of the most significant and frequently encountered physical evidence associated with forensic investigations of death and violent crimes. The circumstances and nature of violent crimes frequently produce a variety of blood stain patterns that when carefully studied and evaluated with respect to their geometry and distribution may provide information of considerable value to assist the investigator in the reconstruction of the crime scene (James, 1999). Blood can be characterized as a fluid mixture composed of plasma and formed elements. The plasma makes up 55% of blood and formed elements make up 45%. Plasma consists of 91% water, 8% protein, 1% organic acids and 1% salts. The formed elements comprise erythrocytes (RBCs), leukocytes (WBC's) and thrombocytes (platelets) (Bevel and Gardner, 2000). When force is applied to fluid, it displaces in some manner in response to the force. The displacement of blood by external force results in formation of a spatter. The formation of spatter may provide important clues to the investigator regarding manner of contact and dispersion of blood (Bevel and Gardner, 2000). Observable differences are seen in size and distribution of blood droplets on the surface they contact or impact. The blood released will hit different surfaces at a variety of different angles. This can be used to determine the point of convergence of the blood spatter. The point of convergence is a common point in which all the individual bloodstains can be traced. All the blood stains when measured along their longest axis or the length of the stain, will come together at a point on that surface, also showing the direction from which they came and their direction of travel. For example, if there are several blood stains on the floor, the various stains can be measured and followed along the length of the stains, and all the lines will come to a common point. It is at this point where all the lines will intersect and the point of convergence is found (Becker, 2009) [3]. The basic type of bloodstain patterns includes:
Disruption of blood at a point source (radiating spatter patterns) Dispersion of blood over time and space from an object in motion (castoff patterns) Dispersion of blood from a point source as a stream under pressure (projected patterns) Gravity induced patterns

(drip patterns) Stains resulting from contact (contact/transfer patterns) Volume patterns (pools, flows) (Bevel and Gardner website) The pattern formed by a blood drop mainly depends upon the direction, angle, force with which it impacted the surface (i.e. low, medium or high velocity) and its source i.e., weapon or body. The special properties of blood such as viscosity, surface tension and specific gravity play an important role in the pattern formation.

For crime scene investigation in cases of homicide, the pattern of bloodstains at the incident site is of critical importance. The morphology of the bloodstain pattern serves to determine the approximate blood source locations, the minimum number of blows and the positioning of the victim (Buck *et al*., 2009) [5].

Bloodstain pattern analysis can provide insight into a sequence of events associated with a violent crime. For example, a 28 year old man was shot using a pump-gun. The study of bloodstain pattern analysis revealed that the biological stain pattern (i.e. bloodstains and brain tissue) showed back spatters from the shot entrance wound on the back of the head, while the victim was lying face down and the suspect was standing close behind his head (Kleiber *et al*., 2001) [6].

The morphology of bloodstain distribution patterns at the crime scene carries vital information for a reconstruction of the events. Bloodstain pattern analysis can be critical to accurate crime scene reconstruction. When it comes to firearm fatalities, the main goal of forensic analysis is to distinguish firearm suicides from homicides and accidents. Apart from the location of the entrance wound, wound path trajectory and gunshot residue, blood stain pattern analysis of gunshot-related back spatter on the hands of the victim can be an essential tool not only to determine which hand was holding the firearm, but also to reconstruct the position from which a weapon was fired (Kunz *et al*., 2013) [7]. The suicidal infliction of two gunshot wounds to the head represents a critical issue for medico legal investigation. Investigators should be careful when interpreting gunshot wound morphology at the scene

The earliest known significant study in bloodstain interpretation that has been documented and preserved was conducted by Pitrowski (1895) [8]. The origin, shape, direction and distribution of the bloodstains following head wounds caused by blows had been described. Kirk (1955) [9] prepared an affidavit regarding his findings based upon bloodstain evidence to the court of common pleas in the case of state of Ohio vs. Samuel Sheppard. This was a significant milestone in the recognition of bloodstain evidence by the legal system. The further growth of interest and use of the significance of bloodstain evidence is a direct result of the scientific research and practical applications of bloodstain theory given by MacDonell and Bialousz (1971-1997) [10a]. In 2003, Benecke and Barksdale talked about the general conditions in which the fly artifacts can be found at a crime scene and described the major differences between blood spatter and fly artifacts. Walter (2005) studied the effect of variations in the uncertainties of angle of impact and discussed the points which can be used to minimize the errors in determination of point of origin in space. Smith *et al*., (2005) [13] studied the diameter and velocity of the blood drops striking the surface by measuring the size of the stains and counting the spines formed on impact. Padosch *et al*., (2006) [14] described for the first time a case of suicidal infliction of two simultaneous gunshots to the head (oral, temporal) with Action 4 expanding ammunition. Connolly *et al*., (2012) [15] studied the effect of variations in impact angles on the determination of point of origin of bloodstains. Recently in 2013 Kabaliuk and Jemy studied the size of blood droplet falling freely under the influence of gravity from objects which are representatives of hand held weapons. The study of bloodstain pattern analysis has emerged as a recognized field in forensic science but this field is yet to gain popularity in India.

In the present investigation blood from four commonly found animal species i.e. human (*Homo sapien sapiens),* pig (*Sus scrofa domestica*), goat (*Capra ibex*) and chicken (*Gallus gallus*) was allowed to fall from a fixed height of 14 inches at various surface angles. The variation in length of blood stain patterns was studied, taking red ink as control.

2. Materials and Methods

2.1 Sample collection

The blood samples of pig (*Sus scrofa domestica*), goat (*Capra ibex*) and chicken (*Gallus gallus*) were collected, labeled and packed from various butcher shops in Patiala city, Punjab, India. The Human (*Homo sapien sapiens)* blood was collected from the blood bank of Deep Hospital opposite to Punjabi University, Patiala. Blood samples were collected in 100 ml clean plastic vials using EDTA as anticoagulant and were used for the practical purpose almost immediately.

2.2 Experimental design

A pointed knife was clamped with stand at a distance of 14 inches from the base of the stand, for studying the variation in pattern due to change in surface angles, wooden blocks were cut at different angles (90°-10°) by using protector and saw. Around 60 ml of blood was taken into a small beaker and pointed edge of knife was dip into it till 2cm of length. The blood was then allowed to fall freely on the paper attached to these wooden blocks.

2.3 Photographic documentation

The photographs of blood stain pattern was also taken using canon power shot A 430 camera (4 mega pixels resolution) on macro mode, with scale.

3. Results and Discussions

The shape of the blood stain pattern formed and the angle at which blood droplet strikes the surface has a mathematical relation. More acute the angle of impact more would be the length of elliptical pattern. The variation in length at different angles and inter-species variations are seen, which can be related with the differences in physical properties of the blood in various species.

Figure 1 shows the various patterns formed by ink control when the drop of red ink is made to fall from a fixed height of 14 inches at various angles such as 10°, 20°,30°, 40°, 50°, 60°, 70°, 80° and 90°.

Impact at low angles 10-30° produces elliptical stains. The elliptical shape is produced due to skidding of drop on the impact surface. With increasing angle of impact the shape of stain becomes circular. At an angle of 90° the stain is circular in shape with spiny edges. The widest point of the blood stain is called the center and the narrowest point shows the direction of travel.

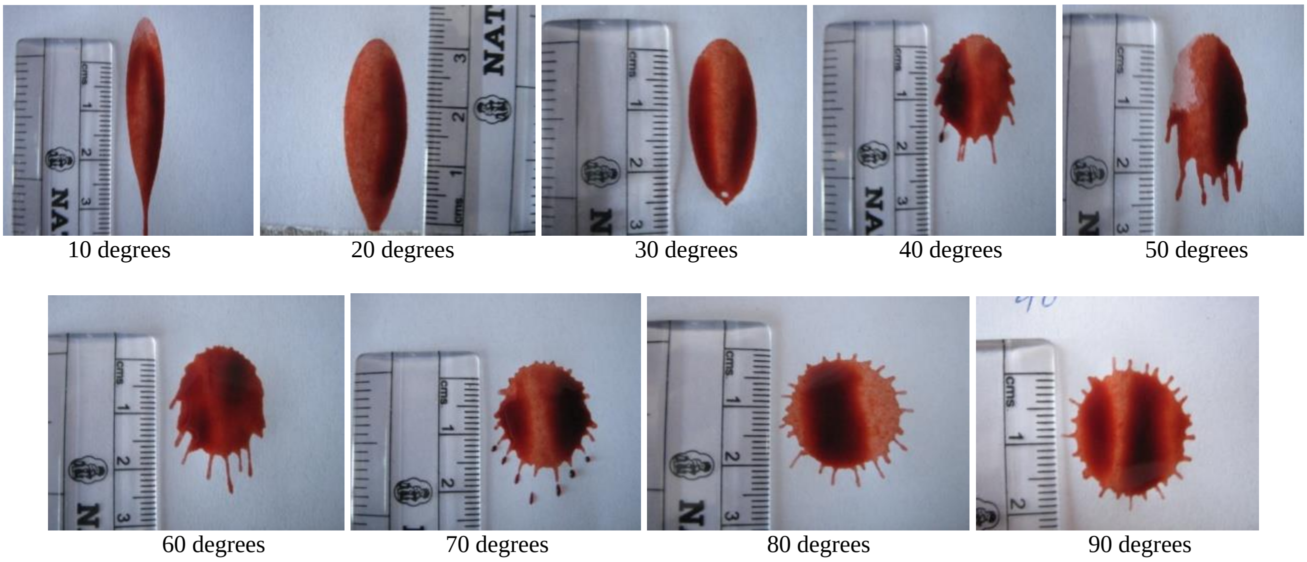


Fig 1: Various patterns formed when the ink is made to drop from a height of 14 inches

Figure 2 shows the blood stains formed when human blood is allowed to fall from a fixed height on a non horizontal surface. The stains formed are called drip stains or patterns because they are formed by the force of gravity acting upon the liquid blood.

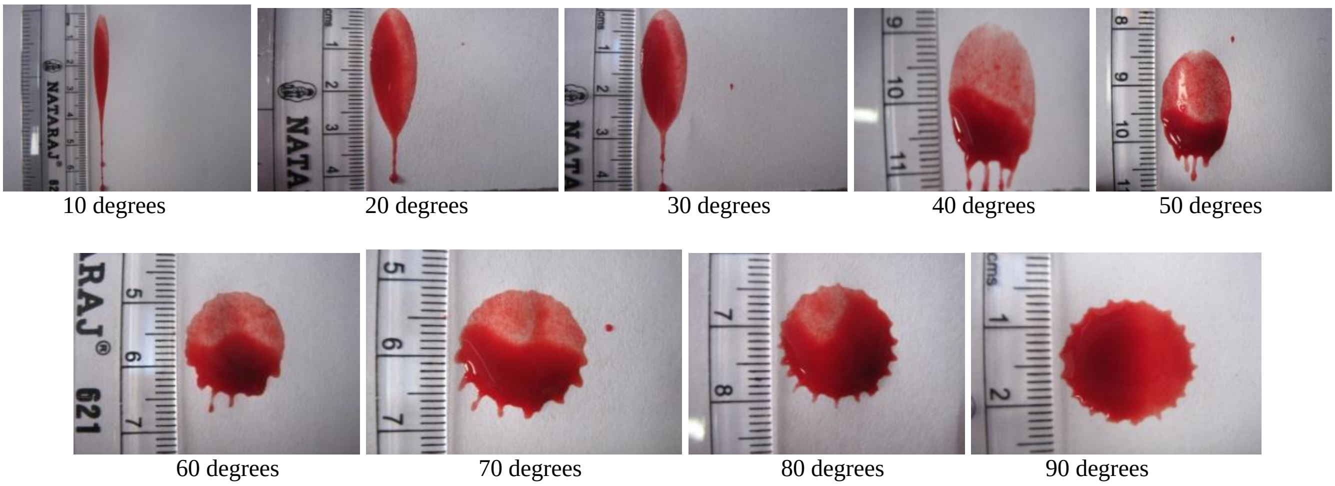


Fig 2: Various patterns formed when human blood is made to drop from a height of 14 inches

Figure 3 shows the blood stain patterns formed by the pig blood (*Sus scrofa domestica*) on non horizontal surface at various angles.

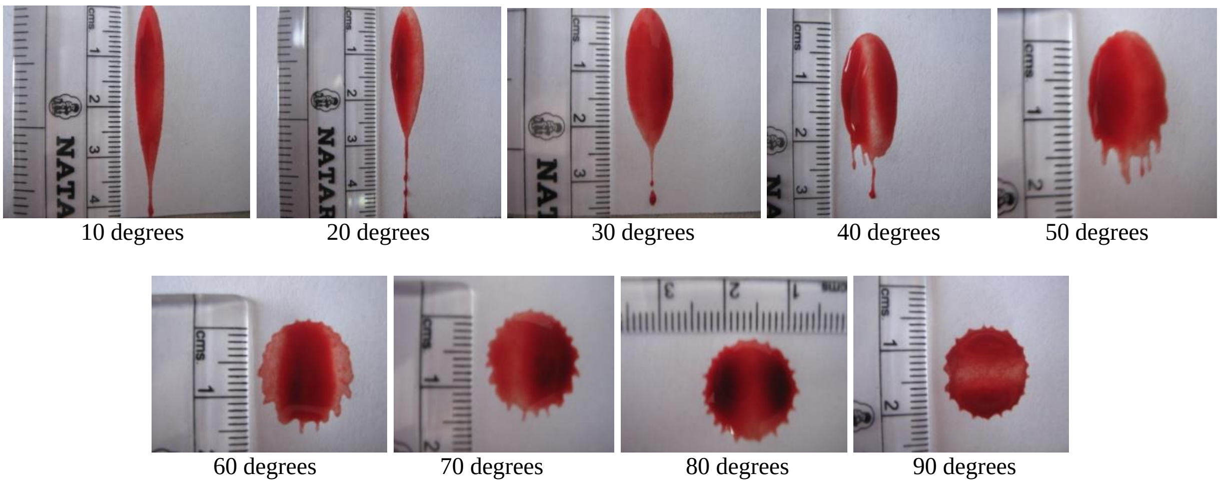
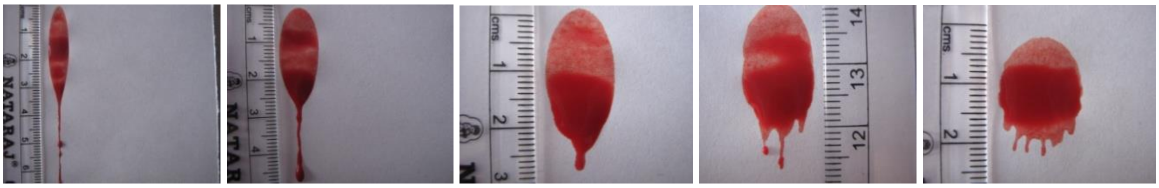
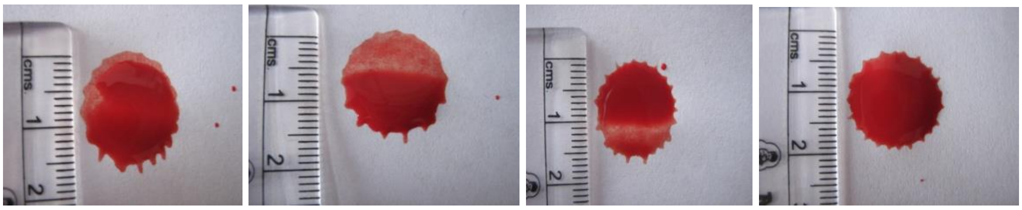


Fig 3: Various patterns formed when pig blood is made to drop from a height of 14 inches

Figure 4 shows the blood stain pattern formed by the goat blood (*Capra ibex*) on non horizontal surface.



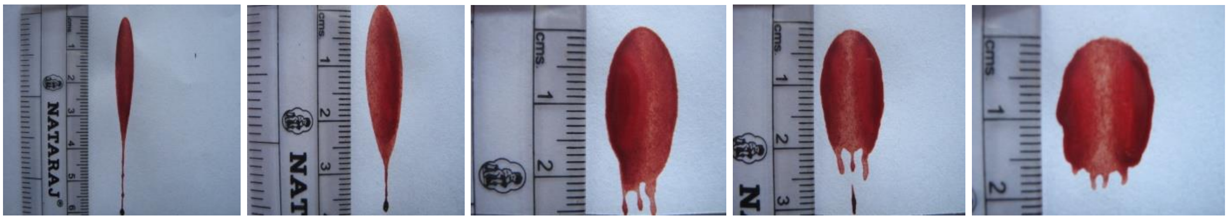
10 degrees 20 degrees 30 degrees 40 degrees 50 degrees



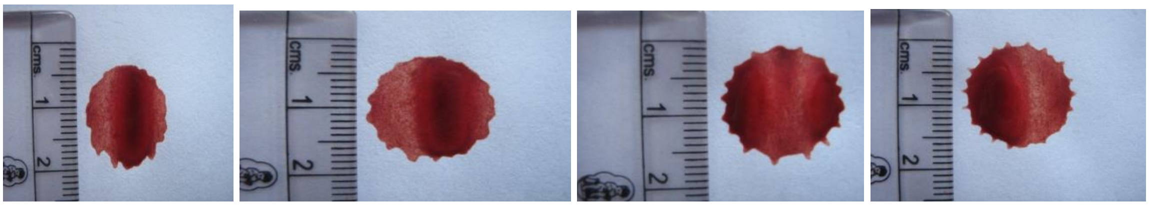
60 degrees 70 degrees 80 degrees 90 degrees

Fig 4: Various patterns formed when goat blood is made to drop from a height of 14 inches

Figure 5 shows the blood stain pattern formed by chicken blood (*Gallus gallus*) on non horizontal surface.



10 degrees 20 degrees 30 degrees 40 degrees 50 degrees



60 degrees 70 degrees 80 degrees 90 degrees

Fig 5: Various patterns formed when chicken blood is made to drop from a height of 14 inches

Table 1 shows the length of patterns formed by blood of different species of animals on surface having different impact angles. The angle of impact of blood spatter is the angle of the blood as it strikes a contact surface. With variation in impact angle from 10°-90° there is decrease in length of blood stains formed. The maximum length of blood stain is seen at an angle of 10° (ink control-36mm; human-39mm; pig-38mm; goat-35mm and chicken-37mm) and minimum length is seen at an angle of 90°(ink control-15mm; human-13mm; pig-13mm; goat-14mm and chicken-14mm). In addition similarities were seen in length of blood stain pattern formed by human and pig blood. Since there are similarities in physical properties of human blood and pig's blood, therefore due to the biohazard risks associated with using human blood pig's blood can be a valid alternative for crime scene reconstruction (Williams *et al*., 2012) [17].

Table 1: Variation in length of blood patterns of four common animal species

Angle	Length of patterns (in mm)				
	Ink control	Human	Pig	Goat	Chicken
90°	15	13	13	14	14
80°	16	14	14	15	14
70°	17	15	14	16	15
60°	19	16	16	17	16
50°	22	19	19	20	17
40°	24	21	22	23	20
30°	28	29	27	26	24
20°	32	32	30	27	30
10°	36	39	38	35	37

Violent crimes result in bloodshed. Such incidents are usually a dynamic event between two or more people and involve a certain amount of rage and uncontrolled movement therefore it is likely that an offender will end up with injuries resulting in bloodshed. The potential evidential value of bloodstains is evident, therefore detecting them at the scene of crime is important and worth the effort (Boon, 2012) [18].

When external forces are applied on the liquid blood bloodstains and bloodstain patterns are deposited on various surfaces, including the clothing of the individuals present at the crime scene. The analysis of bloodstain pattern yield valuable information regarding the events that resulted in their formation, when examined by a qualified analyst. The information gained can then be used for the reconstruction of the incident and the evaluation of the statements of the witnesses and participants of the crime.

At crime scene the blood can drip from victim or suspect's clothing's, wounds/injuries, weapons etc. Experimentally, in the present study, it is demonstrated that when blood is allowed to fall from a fixed height of 14 inches on a non horizontal surface at different angles there is appreciable variation in shape of the blood stain formed. Similar volume of ink control and blood was dropped from the pointed knife. The angle of impact affects the formation of blood stains. At low angles (10°-30°), when the blood is allowed to fall freely through air the blood stains formed are elliptical in shape. With increasing angle of impact the stains formed are circular in shape. In addition there is decrease in length of stains with increasing angle of impact.

Passive dripping, the slow dripping of blood under gravity, is responsible for some bloodstains found at crime scenes, particularly drip trails left by a person moving through the scene. Drips were formed from stainless steel knife in the present study. Dripping of blood produces slightly smaller drops than dripping ink as the viscosity of blood is six times more than water. They offer extensive information and are an important part of a functional, medically and scientifically based reconstruction of a crime.

By analyzing the shape and size of blood stains left behind at most crime scenes allows the investigators to determine the angle at which the blood drop strikes the surface as the formation of blood stain is dependent on the angle of impact. The shape of a resulting bloodstain is often changed when the angle at which it impacts a surface is changed. This is also confirmed by Lee, (2001) [19] and (Lyle), 2004.

These components, when correctly analysed, can help to reconstruct the event that led to the formation of bloodstains at crime scenes. Blood has a different viscosity, adhesion, capillary action, and density. Hence these factors, after examining in a laboratory, can be translated to crime scenes.

Bloodstain pattern analysis is based on principles of physics. When the blood drops freely under the influence of gravity it takes the minimal shape due to effect of surface tension and assumes a spherical shape. As a drop of blood falls it will reach its terminal velocity, or the maximum speed the drop can reach in air. The analysis of bloodstains left at crime scenes throws light on various forensic matters including reconstruction of events; differentiate between homicide/suicide/accident and identifying areas with high likelihood of offender movements for taking DNA samples.

To associate bloodstains with particular individual using blood stain patterns for reconstruction of events, provides mutually valuable sources of physical evidence. The proper interpretation of bloodstain evidence has proved crucial in numerous cases where the manner of death is questioned and the issue of homicide, suicide, accident or natural death must be resolved in a criminal or civil litigations or proceedings.

The morphology of bloodstain distribution patterns at the crime scene carries vital information for a reconstruction of the events. The analysis of bloodstain morphology can differentiate between stains of different species. Different blood stains are formed by blood of different species (human, pig, goat, chicken) in the present study. The similarities in length of blood stains between human blood and pig's blood, at different angles hence pig's blood can be used as a substitute for human blood in bloodstain pattern analysis research and crime scene reconstruction.

The advantages the present study are the short preparation time and the non contact measurement of blood stains. This method gives accurate results regarding the size and shape of bloodstains on victim, suspect, or on the walls, ceilings, floor at a crime scene, formed at different angles. It may have practical applications in estimation of impact angle in forensic cases.

A highly qualified analysis can help to estimate facts concerning the location, quality and intensity of an external force. This study shows that a detailed questions connected with the reconstruction of the crime can be answered and it may have practical applications on a wider basis.

4. Summary and Conclusion

This technique for crime scene reconstruction using blood stain patterns will provide key to recreating the events of a crime and possibly solving a crime. It often serves to reconstruct events at the crime scene and to shed light on specific matters.

To be presented accurately and usefully in court, bloodstain evidence must be recognized, documented, preserved, and correctly evaluated. Bloodstain pattern analysis is a valuable tool to help explain blood-shedding events. When a blood drop impacts a surface at different angles the blood behaves very differently. The length of the resulting bloodstain increases as the angle of impact increases. The analysis of shape and size of blood stains shows that there are inter species variation in blood stain with respect to the diameter, shape and length of the elliptical pattern at various angles when blood from selected species and ink control were made to fall on the surface under similar conditions.

These variations may help to differentiate between a real crime scene and a simulated crime scene. The analysis of crime scene provides a snapshot of what took place over the course of seconds, minutes, hours, and even days. Hence the results obtained indicate that the knowledge of blood stain patterns may help an investigator to confirm or refute assumption concerning events and their sequences.

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