8 Blood and Blood Pattern Analysis

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8.1 Introduction – Analysis versus Observation

The Locard principle is used by forensic scientists to explain the transfer of evidence. It is not possible, according to Locard's principle, to enter an environment and not change it in some manner by either leaving something behind or taking something with you. *Every contact leaves a trace* and with blood there is an initial non-specialist observation that blood spilled at a crime scene is just too messy and adheres to everything.

'Why?' asks the lay observer 'do you need Locard to explain a bloodstained crime scene?'

Crime scene blood pattern analysis is an observational tool. You can take a blood sample from an animal or a crime scene, but you cannot take a blood *pattern* from either. You must first record a blood pattern in order for it to be analysed and interpreted.

Blood pattern analysis is a highly specialized form of forensic science and consists of three independent and linked components.

1. Analysis.
2. Photography (and documentation).
3. Interpretation.

8.2 Definition

Blood pattern analysis means to examine, inspect and record the shape, location and distribution patterns of bloodstains.

The underlying premise upon which all bloodstain analysis depends is that all patterns, shape, location and distribution of bloodstains are characteristic of the forces that created them.

And in this simple descriptor we have the physicists and mathematicians taking the guesswork out of a biological sample investigation. Blood samples will always vary in appearance, but the forces that create them are always the same.

8.3 Blood

Blood is an imprecise medium to examine forensically. No two circulating red blood cells will behave in the same manner or have the same colour, appearance, weight, hue or oxygen saturation. Some red blood cells have nuclear (DNA) material, while others (most) don't. With large variations in size, shape and chromaticity, blood is too difficult to be described in a forensic sense.

Forensic scientists who are experienced at blood pattern analysis, then, don't describe blood that has been found deposited outside the body at a crime scene, but instead they attempt to describe the patterns that blood forms which are *characteristic of the forces* that have created them.

All blood cells are slightly but sufficiently different between species – we know that one can't give a dog a blood transfusion from a cat. There are differences between the blood from individuals of the same species (blood type) and even blood from within the one animal (blood maturity): all red blood cells are similar, but they are not the same.

Regardless of this variation, there are some facets that blood can share with other blood. All blood cells, regardless of inter- and intra-species variation, will obey the rules and laws of physics, fluid dynamics and motion. It is these forces that forensic scientists utilize to describe the creation of blood patterns. This chapter is, by necessity, a bloody lesson in physics and motion. And while there is variation between one red blood cell and its immediate neighbour, there is no variation in the *type* of forces that will act on any number of red blood cells to produce a bloodstain pattern. The shape which the blood pattern will take when blood is deposited on a receptor surface is due to the forces of motion, fluid dynamics, friction, surface tension, viscosity, adhesion, cohesion and gravity.

The blood leaves a telltale pattern of the forces that created it and this is captured by a camera, a sketch or a video recording.

This is what bloodstain pattern analysis is: a *force pattern analysis*, captured by photography and documentation. This step in the process is relatively simple; it is the next, the same issue that affects all aspects of forensic analysis, which is complicated – the interpretation.

8.4 Analysis versus Interpretation

When presenting bloodstain patterns in court, it isn't (usually) the analysis that will be argued against. In that case, you would be (foolishly) arguing against Isaac Newton, Robert Brown, Archimedes and their colleagues, and, in a legal dispute, the barristers find it easier to argue with you, not them, over *your interpretation* of *their laws* of physics and motion applied to the blood pattern analysis.

Beginners in this area should focus on the analysis at the crime scene through accurate documentation and, in particular, the taking of methodical photos. You can then hand over the photos to a more qualified, competent or confident expert to interpret in a laboratory or office setting.

And here we can be discussing blood spatter, hair microscopy or soil samples, as one of the fundamentals of forensic science is entwined with the skill of blood pattern *analysis* and the subsequent procedure and art of *interpretation* of the patterns formed by the forces acting on the blood to create that pattern. While many vets and animal workers are familiar with the taking, analysis and subsequent interpreting of a blood sample from a sick animal to arrive at a clinical decision (based on haematology and biochemistry) for that animal, they are also aware that two vets will arrive at different interpretations of the same clinical blood result. Bloodstain analysis is no different. Two independent blood pattern experts can interpret one blood pattern in two different ways, and this is the basis for the competitive nature of science and an adversarial philosophy of legal disputes.

Most readers will be able to take photos of a blood pattern. This is part of the analysis; however, many need to understand the separation of the analysis step from the interpretation step in forensic science. While very few responders will (willingly) be able to interpret the blood pattern left at a crime scene correctly, most of them can take accurate images and process the scene accurately enough for another expert to assist later in the investigation. You are in this field first as an analyst in the form of a photographer and documenter, and second as an interpreter of the patterns you record. This is where there are differences between crime scenes involving animals and humans; wherein the latter will always attract a skilled blood pattern analyst, and perhaps a proficient forensic photographer, while the former will attract whoever happens to be available and has a good camera.

Blood shed outside an animal's body becomes clotted due to the clotting factors within and the external temperature of the environment it has been deposited in. Deposited blood sticks to hair, clothing, furniture and buildings, and is a persistent witness to a crime. Blood yields a lot of information, clinically, temporally and forensically.

Another chant repeated throughout this book is the discrete independent effect. Blood patterns or any piece of evidence should not be taken in isolation. There should always be at least two independent sources of evidence gathered from any crime scene. For example, a photograph from a bite wound and a salivary swab for DNA analysis taken from the bite wound. Another example is an eyewitness statement and an image produced from a CCTV camera. As long as there is more than one source of evidence and one source is independent from the other. One hundred photographs are 100 different types of the same singular source of evidence. Blood is ideal in that it comes with its own built-in secondary evidence source – DNA. This is useful if DNA is what you need. If you recover blood from a scene for later DNA or toxicological analysis, always photograph it first as a pattern, drop, stain, smudge, spurt, misting, drip, satellite pattern, low-, medium- or high-velocity deposit, back spatter, wipe or cast-off stain, because the pattern created cannot be reproduced after you have sampled it for a secondary source of evidence.

Blood provides many clues as to the temporal sequence of events that have occurred, as well as distance from an animal to determine whether, for example, a shooting incident was accidental or deliberate. Blood also provides information as to the behaviour of the animal. The correct analysis of blood patterns can provide a great deal of information for both prosecution and defence experts to interpret.

Photography of blood and the patterns and stains it can make can be described as evidence collection and analysis, but already an interpretation has been made. This dull red pattern that has collected under this dead animal – is it blood?

How do you know?

8.5 Presumptive Screening of Blood

When we see a red, thick and clotted stain that is expanding slowly under a dead animal, it is likely to be blood. We transcend the boundary between veterinarian (it is blood) to forensic scientist (it is likely to be blood). But even before we approach this question we need to run through the PREGS protocol (see Chapter 5, this volume) at our scene to make sure it is a safe place. We then inspect (look) or examine (look and touch) the animal to determine life-extinct status. Once we have satisfied ourselves the scene is safe and the animal is no longer alive, we then protect the scene and start to gather and document available evidence. In this case, photos, sketches and video.

To ensure we can answer the question in court, 'How do you know it was blood?', we test it.

Presumptive testing of blood can be done in a variety of ways, but the most common manner that many vets and animal workers will be familiar with is the simple Hemastix – see Fig. 8.1.

Most blood presumptive tests rely on the catalytic properties of blood and the presence within a red blood cell of the haemoglobin protein. So a presumptive test for animal blood will be the same, regardless of the species tested for. And armed with the knowledge that very few things in nature contain haemoglobin, we can satisfy ourselves after testing that the bright red thick material is blood. We have analysed the blood from two sources. The first is our prior knowledge, experience and expectation of dealing with what blood is and what blood looks like, and the second, independent source is the presumptive test for blood – these two independent sources provide two separate analyses and one interpretation: *we have blood.*

While the Hemastix presumptive test suggested has been used by veterinarians in clinical practice (there are rules for the admissibility and reliability of any evidence you introduce to a court), for simplicity, the evidence must satisfy two criteria. It should be accepted by your peers *and* it needs to be verifiable. While the lack of a presumptive test for blood prior to subsequent scene processing and analysis should not affect the admissibility of the evidence (photograph and documentation) to a court, it may affect the weight which the court attributes to that evidence.

Fig. 8.1. Hemastix test for blood.

8.6 What Is Blood?

Blood consists of red and white blood cells, nutrients, dissolved gases and blood platelets carried around in plasma. Erythrocytes (the red blood cells) have the role of transporting oxygen to the cells of the body. These body cells have an obligate demand for oxygen molecules (O_2) in their respiration cycle and willingly donate a carbon dioxide molecule (CO_2) to the plasma after this exchange, allowing the erythrocyte to spend the second part of its journey oxygen and carbon dioxide free and as a willing servant awaiting the next oxygen molecule to bind with in the lungs, air sacs or gills of its host.

It is the liquid plasma component of blood that acts as the main carrier of CO_2 back to the lungs. This can be visualised when comparing bright red arterial oxygenated blood with that of the venous dull hue of de-oxygenated blood. It is this colour differential that has allowed the application of pulse oximetry in determining the oxygen saturation of a patient's blood in veterinary and human *clinical* medicine. This is our first forensic observation – what colour is the blood?

Colour of blood is determined by the amount of oxygen present in the blood at the time of recording the blood pattern, as well as the time that has elapsed since blood has been deposited on the surface.

Anhydrous blood should not be confused with clotting stage. This is not a clinical examination of blood, and the ability of the blood to dry out depends on volume and shape of the stain as well as environmental conditions such as humidity, temperature and wind exposure.

It is also the colouration of red blood cells and subsequent discolouration due to breakdown of this haemoglobin/iron molecular complex that can cause considerable difficulties in the ageing and interpreting of the appearance of a bruise in *forensic* medicine. Haemoglobin and iron molecule complexes exist within an erythrocyte to transiently capture and transport a molecule of oxygen around the body, allowing it to diffuse through the erythrocyte cell membrane to the target cell. In order for a red blood cell to get close enough to a target body cell, it needs to be able to squeeze through a capillary. Red blood cells are approximately 25% larger than the diameter of their capillaries (Snyder and Sheafor, 1999). There is (naturally) variation between species as to this exact figure; however, the overriding principle remains that the erythrocyte must be bigger than the capillary it enters. This counter-intuitive set-up prevents carbon dioxide-rich plasma from interfering with the transfer of oxygen between the erythrocyte cell membrane and the target cell, a process that requires uninterrupted membrane-to-membrane contact between the erythrocyte and target cell.

This process of transient cell-to-cell contact requires a red blood cell to retain a rigid cell membrane while maintaining surface flexibility. Like skin cells, all mature mammalian red blood cells have no nuclear material. Most, but not all, mammalian erythrocytes are shaped like biconcave discs; when squeezed through a small capillary this shape and integral membrane rigidity allows the blood cell to assume a cigar shape, thus allowing maximum surface area for oxygen transfer from the red blood cell to the target cell – a passive diffusion process that must not be interfered with by the presence of a surrounding layer of carbon dioxide-rich plasma. This design also allows the erythrocyte to act in many ways like a bullet travelling through a gun barrel. Bullets are (also counter-intuitively) larger than the barrel they travel in and this ensures that the gas build-up behind them pushes them out of the barrel.

Different mammalian and non-mammalian species have distinctive shaped and nucleated erythrocytes, and this allows them different properties with respect to blood flow (laminar or turbulent), blood viscosity, oxygen transfer and cell membrane flexibility.

8.7 Blood Spatter – Overview

Bloodstain pattern analysis is the evaluation of the size, shape and distribution of patterns that are identified in blood. The purpose is to

possibly identify the activities that took place to deposit the blood, and to identify the location of the individual animal victim(s) during the bloodshed. The first step involved is identifying basic patterns. By identifying patterns an analyst can then draw conclusions as far as what type of activity took place to create those patterns. Those are recognizable patterns and they are reproducible patterns.[1]

Although in-depth interpretation of blood spatter and bloodstains requires some training and experience, an investigator should be able to look at blood patterns, make some basic deductions, and document these. A simplified introduction would ask the reader to recognize and describe the basic blood pattern and focus on the forces that caused the patterns. The use and application of trigonometry and an understanding of physics, applied to biological material (blood) is what the forensic scientist needs and the courts prefer. While a biological component will always exist to blood and blood patterns, and these biological properties are of use in a clinical sense, the forensic examination of blood compels us to preferentially observe the forces used to create the blood pattern and not biological components.

Correct interpretation of blood spatter can reveal the position and location of the animal victim at the time of death. A dead animal found in a pool of blood may have died in that pool of blood and an animal that is found on a clean floor may have been killed somewhere else and placed at the scene.

Blood spatter patterns and an understanding of the forces that created them can determine the injuries suffered; location of the victim with respect to other physical evidence; which events occurred and, importantly, which did not; and the temporal sequence of events that other forms of static evidence can't provide.

Temporality of events is perhaps not surprising given the abundance of equations in the physical science that require forces, speeds and distance to be measured over a period or function of time.

When analysing a blood pattern, the absence of blood or blood spatter may be just as important as the presence of blood spatter.

Blood spatter requires full documentation primarily by photographs and sketching and should be considered as part of the analysis of the whole scene.

Specialist lighting and chemical enhancement are particularly important in photographing bloodstain patterns.

8.8 Record: Mnemonic – CAPSS

a. *C*olour of the stain
A trained examiner (e.g. a veterinarian) can determine whether a bloodstain is venous or arterial blood by the brightness of the red hue, which is caused by the amount of oxygenated haemoglobin present. It should be noted that the oxygen/haemoglobin bond is, by necessity, a weak bond, so that arterial blood deposited on a surface for a significant period prior to examination may not retain its characteristic bright red hue.
b. *A*nhydrate
Wet, dry, drying (avoid use of the term 'clotting', as we are making a transition from clinical veterinary science into forensic veterinary science).
c. *P*osition of a stain
Wall, floor, ceiling, under animal.
d. *S*ize of the stain, as well as the border characteristics of the stain
Diffuse, discrete.
e. *S*hape of the stain
Amorphous, round, pooled.

Once we have our PREGS protocols (see Chapter 5, this volume) and subsequent CAPSS analysis completed, we can analyse and interpret the recorded evidence with an accumulated forensic knowledge of physics and fluid dynamics, and then combine this with our clinical knowledge of animal behaviour, clinical and gross pathology, clinical disease, and prior crime scene processing and clinical experience to describe *what events occurred* to create those patterns. We have transferred from being an analyst to interpreting the signs, and again we need to ask for an independent (second source of evidence) person to assist with their view of the analysis.

8.9 Forces Acting in Blood

8.9.1 Cohesion

Cohesion is a force that acts within a drop of blood (or any liquid) that gives the liquid certain properties such as surface tension. It allows molecules within the blood drop to resist separation and causes a blood drop to form a distinctive tear shape characteristic of this force (see Fig. 8.2).

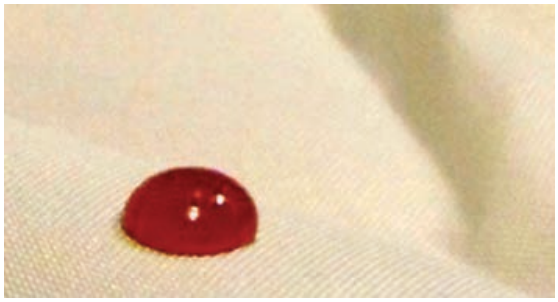

Fig. 8.2. Cohesive forces acting on a blood drop.

8.9.2 Surface tension

Surface tension is a result of cohesion forces, the elastic-like property of blood or any liquid that makes it tend to contract, caused by the cohesive forces of attraction between the molecules *within* the liquid. The molecules on the liquid surface have a net force on them that pulls them toward the centre of the liquid. All other molecules in that liquid will have equal forces of attraction to them as they are surrounded by other molecules. However, the surface molecules are incompletely surrounded by other molecules. This results in a net attraction toward the underlying molecules and away from the surface, causing a 'skin' to be formed on the liquid surface (see Fig. 8.3).

8.9.3 Viscosity

Viscosity of a liquid is a measure of that liquid's resistance to changing shape. *Thicker* fluids are more viscous fluids. *Thinner*

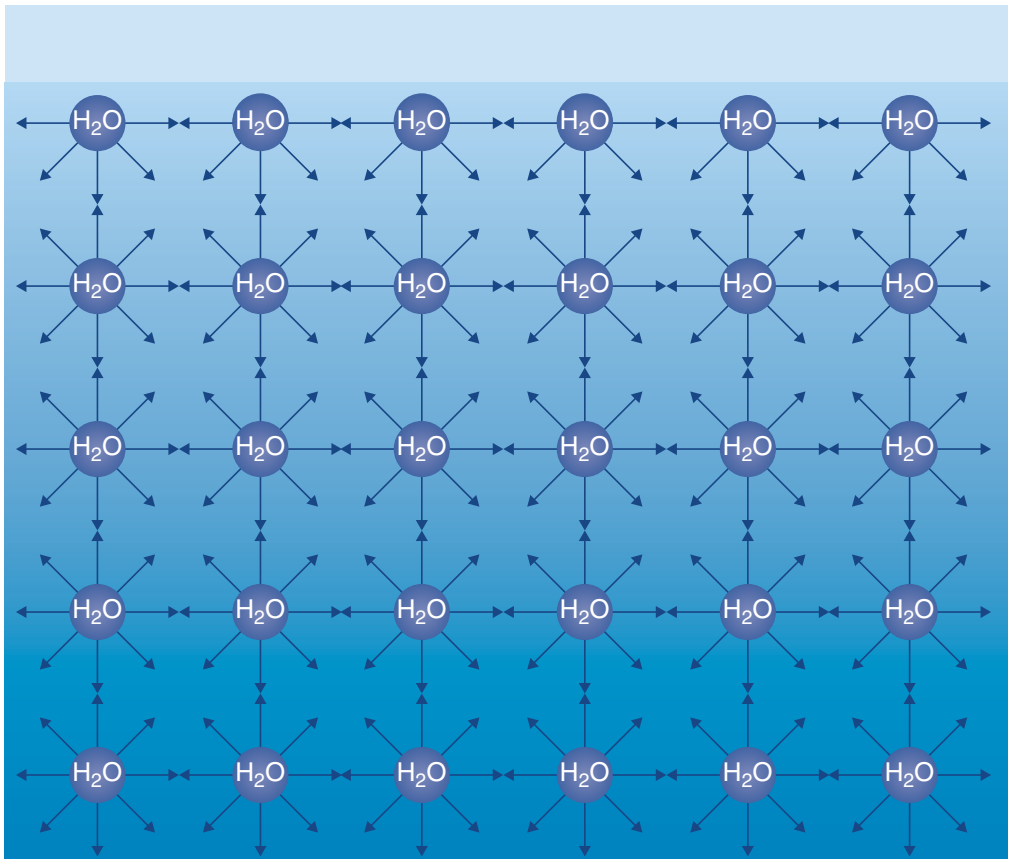

Fig. 8.3. Surface tension: the top layer of molecules (only) is pulled downward; every other layer of molecules is pulled equally in all directions.

fluids are less viscous fluids. Blood is (literally) thicker than water and four times more viscous.

When a liquid such as water is squeezed and projected out through a water pistol, the harder you pull on the trigger, the faster the water comes out of the pistol. This is called a constant viscosity – the harder you squeeze the water, the more resistance the water exerts back against the trigger, and the faster it exits the water pistol.

Blood is slightly different to water in that it doesn't act with a constant viscosity; while blood is four times more viscous than water, when there is a force applied to blood it becomes less viscous (and *thinner*). So when squeezed through a syringe (or small capillary) it becomes easier to squeeze out the harder you press. This property of blood allows it to flow easily through small blood vessels.

8.9.4 Adhesion

When blood strikes a recipient object, it sticks to that object through adhesive forces. Adhesion forces differ from cohesive forces, and for blood to stick to an object the forces of adhesion must exceed those of surface tension cohesion.

8.10 Forces Acting on Blood

1. Force of ejection – arterial spurt or external force (usually a trauma).
2. Gravity.
3. Elasticity of the surface it is in contact with.

Blood will usually leave the body through some form of trauma or externally applied force. It is then immediately affected by gravity and the 'bounce' or the elasticity of the recipient surface.

All three external forces combine to impart a pattern that can be seen in the blood drop or stain.

A blood drop striking a surface with little or no distortion will appear 'perfect' (see Fig. 8.4).

Fig. 8.4. Blood striking a glass surface with little or no distortion to its edge.

8.10.1 Biological forces acting in blood serum

Clotting factors: when we describe clotted blood as forensic scientists we use terms such as dry, drying or wet to assist in the transition from clinical veterinary science (clotted appearance).

8.11 Photography and Analysis

Photography is the key tool for the documentation of bloodstain patterns. When used correctly, a skilful photographer can not only document the scene, but also assist in the post-scene analysis through the correct use of perspective in the taking of photographs. In an animal crime scene that does not involve humans, it is unlikely that a trained blood pattern analyst will attend; however, if required, a trained human blood pattern analyst can look at photos that have been taken at the scene and can assist with or provide an interpretation post-scene.

A blood pattern examiner can provide an interpretation of a scene through careful evaluation of accurate and precise photography. A requirement for a small amount of knowledge in photography is needed beyond 'point and shoot' capabilities; however,

the extra photographic skills required are not outside the aptitude of most people and modern digital cameras.

All evidence at scenes, including blood pattern-containing scenes, usually require three starting shots. Overview, approach and close-up – usually with the same numbered indicator in the photo that corresponds to a photographic log to assist with evidence identification and continuity.

Figures 8.5–8.7 show an overview (Fig. 8.5), approach (Fig. 8.6) and close-up (Fig. 8.7) of a bloodstain in a trailer. No photographic markers have been used in these images and no scale has been used in the close-up. It would be difficult to understand the sequence of events if only Fig. 8.7 was adduced as evidence.

8.11.1 Close-up of bloodstains

Have the camera at a perpendicular angle to the surface that is being photographed. This is important as, with the addition of a measuring scale and basic computer programming, the measurements can be made of blood drop size and the spacings between them (see Fig. 8.8).

In the example in Fig. 8.8, I have taken a photo of blood on a horizontal surface with my camera perpendicular to the surface, and included a scale. I have uploaded the image to my computer, opened a software program and cut-and-pasted the scale to overlay the blood drop. So I know that the diameter of the blood drop of interest is 5.5 mm (see Fig. 8.9).

Similarly, I can calculate the distance between drops in the photo after the scene has been processed, not necessarily at the scene.

The only requirements for this to be accurate are:

1. Camera perpendicular to the object being photographed.
2. Inclusion of an accurate scale.
3. Access to a PC or Mac that can perform cut-and-paste tasks – Microsoft Paint is a good one for non-Mac users.

Fig. 8.5. Overview of a trailer with the side door opened: bloodstained partition in trailer visible.