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ÉTUDE DES GOUTTES DE SANG PROJETÉ

PAR

V. BALTHAZARD, R. PIÉDELIÈVRE, Henri DESOILLE et L. DÉROBERT

L'aspect des taches de sang permet dans une certaine mesure de déterminer le point d'émission des gouttes qui les ont formées. Nous nous sommes efforcés dans ce rapport de préciser les éléments susceptibles de fournir à ce sujet des indications utiles. Il est évident qu'avant d'essayer de voir clair dans une affaire criminelle, il faut d'abord savoir d'une façon générale comment les gouttes de sang font issue hors des plaies, quelle est leur trajectoire dans l'air, comment se forment les taches qu'elles laissent.

Le sang n'est qu'un liquide particulier. D'une façon générale, comment se forment les taches dues aux liquides?

Les physiciens ont longuement étudié les régimes de formation des jets de liquides et des gouttes en lesquelles ils se résolvent. Par contre ils n'ont guère étudié ce que deviennent ces gouttes lorsqu'elles rencontrent un plan solide. MM. Foch et Pérès, professeurs de mécanique des fluides à la Faculté des Sciences de Paris, ont bien voulu vérifier pour nous les bibliographies

R e s e a r c h
on
B l o o d   S p a t t e r

by

V.Balthazard   R.Piédelièvre   H.Desoille   L.Dérobert

A paper given at the 22nd Congres of Forensic Medicine of the French language on the 5, 6 and 7 June 1939
in P a r i s

Translated by my late friend, Karl Schmidt.

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French original paper can be obtained from:
Directeur de L'Institut de Médicine Légale
Université René Descartes , Professeur A. Hadengue
2, Place Mazas, 75012 Paris

Content.

Introduction

The outward aspect of bloodstains permits with reasonable certainty to find the point in the room, from where the drop came, which caused the stain. In this report we tried to pinpoint the characteristic elements, which can give the decisive hints. It is clear, that in order to find the solution in many criminal cases, it is necessary to know beforehand in a general manner, how blood drops exit from a wound, how their trajectory through the air looks like and how a blood drop changes into a blood stain.

Blood is a special fluid. Generally now: how stains develop from fluid drops ?

Physicists have conducted extensive research on jets of fluids and about the drops, constituting the jet. But they did not investigate about what happens to the drop, when it falls onto a solid surface. Professor Foch and Professor Pérès, both from the department of hydrodynamics at the University of Paris, have searched French and international literature on this subject and have confirmed, that physicysts did not yet have engaged in the research upon stains caused by fluid drops.

Research on stains, conducted on the grounds of experimental physics should really precede the research about the application of this knowledge in the forensic medicine. We have undertaken to do this research. Perhaps it would be better, to start with other fluids, than with blood. But in order to show on this congres some practical results, we have nearly exclusively experimented with blood, aiming at the following:

1) To determine the physical laws by which a stain, deriving from a drop, is shaped;

2) To find out, up to which degree it is possible to use these laws in the forensic practice.

The governement enabeled us to do this work by supportin it financially from funds desiganted for scientific research.

One of the problems to solve, was the determination of drop volumes. Drop volumes had to be changed according to necessity. To achieve this, we let drops develop at the end of pipettes. These pipettes had different diameters and different lumina. The drop volume is being determined by the diameter of the pipettes end, not by its lumen.

One end of the pipette containing blood was connected to a long and thin rubber hose. By simply exerting pressure at the end of the hose, there is being formed a drop at the open end of the pipette, which grows until it falls off. Thus we achieved to obtain from the same pipette throughout the whole series of tests, always the same volumes of drops. The force, necessary to cause the drop to fall off is of that magnitude, which is required to cancel the equilibrium between its weight and adhesive strength on one side, and the atmospheric pressure on the other. It is an example of the free fall.

The research on blood drops of known volumes had to be done with blood rendered uncoagulable. We used bovine blood with an addition of "Moranyl" in the proportion of 1 Gram on 300 ccm of blood (309 Poulenc, 205 Bayer). This blood was until its use stored in a fridge. We used also, but seldom, defibrillated blood.

For certain experiments we used fresh blood dropping out of a wound. We achieved this in the following way: We fastened together one front leg and both back legs of a rabbit. The inner surface of the second front leg was shaved so that the blood vessels were visible through the skin. Then we made a small inscision with a bistouri. We he the rabbit at his ears and at the wounded leg. Bleeding wa in drops and under pressure.Drops had very different volum Thus we approached closely the real conditions experienced practically as a result of crime.

The scope of this research exceeds the framework of our own scientific discipline and belongs into the framework of hydrodynamics. Whilst performing this task, we had to observe strict, scientific methods. The research is of course lengthy. We state frankly, that we did not yet solve the tasks completely, and we present here only, what we so far achieved. We will continue to work on this subject.

Experimentally we found a simple technique in order to make drops fall from certain known heights. We fastened a thread obliquely over the target, onto which we wanted the drops to fall. This thread served as a guideline. The bleeding rabbit wound was then held over the target and close to the thread. Then we measured the different vertical distances between the points on the thread where drops were falling off, and the target surface, where the stains were formed.

In order to investigate drops, which do not fall off vertically, but which are projected with force, we used dogs. We punctured the femoral vein of the dog and connected to the needle a syringe (type "Jubé), as it is used for blood transfusions. With that syringe we could then spatter normal, fresh blood into different directions, in different volumes and with different force.

Finally, in order to understand how blood stains are being formed, we made movie pictures with an apparatus given at our disposal kindly by Mr.Bull and Mr. Nogués from the Marey institute. The process we investigated in that way, accured that quickly, that is was necessary to use flash light impulses, produced by means of an electric intermitting device.

Mr.Bull gave us an intermitter for 500 flashes per second, which we could use effectively only over the duration of 1/10 of a second.

We photographed also jets of other fluids in order to find out, how the trajectory looks like. At this work we were assisted by Mr. Desgres and Mr. Degan, from the laboratory of Strohl and Truffert.

Drops falling vertically
onto a horizontal target.

The forensically important question is: "Is it possible to draw conclusions as to the dropping distance of blood drops from the outwardly aspect of blood stains ?"

It is a long known fact, that drops falling from a low point onto a target, form circular, round stains; as the falling distance augments, there are appearing spines on the fringe of the stains.

Question: Does the number of spines answer our question?
Answwer : The number of spines around a stain may depend on two factors.

1) We let drops of uncoagulable blood fall from a pipette of 3 mm diameter and 1 mm lumen. We have choosen different falling distances. We counted the spines on each stain. On the abscisse we marked the dropping distances in cm, on the ordinate the number of spines (Fig.1). We obtained a parabolic curve. We found a rule: Similiar curves we obtained also with other fluids.

2) We let drops fall from the wound of the rabbit, of different volumes but of a constant, known hight (1 and 3 meters). We counted the spines and measured the diameter of the stains. We marked the number of spines on the ordinate, and the diameter of stains on the abscisse (Fig. 2).

We found: The number of spines augments rapidly as the drop volumes become bigger and as the diameters of the stains become bigger. The number of spines depend consequently upon two variables: the dropping distance and the drop volumes.

Now we had to examine, which one of these two variables has the greater influence.

3) We have estimated the approximate drop volume from the stain diameter. The bigger the dropping distance, the bigger will be the stains, caused by drops of the same volumes. We examined the rules, by measuring the diameters of stains, being caused by drops of the same volume, but from different falling distances. The results we marked on a coordinate of the same scale as the previous one; the falling distance on the abscisse, and the staines diameters on the ordinate (Fig. 2)

We found: The diameters of stains are augmenting as the falling distances are rising, but slowly. Comparing the various found data, we concluded, that the number of spines depends less upon the falling distance, than on the drop volume.

4) We found further the following: Out of the wound of a rabbit we let drops of unknown volumes drip down from different hights. It is impossible (Fig. 3) to estimate the falling distance from the number of spines. But it could be established a relationship between the size of the stain and the number of spines (Fig. 4). This is at least valid as an intermediate result, as long as further examinations will not disprove the validity.

Can the length of the spines be of any value?
It varies considerably depending on the circumstances, but it is sufficient to regard Fig 5 showing two stains from two different blood drops, coming from the same hight of 5,60 meters and from the same wound. This is proof enough, that the length of spines is useless, because two completely different shapes of staines are produced by drops from the same falling distance.

Around the stains there are also secondary spatter. We measured the distance between the edge of the stain and the secondary spatter being projected the farthest away, expecting, that this distance will grow proportionately with the falling distance. But also here we did not detect any rule, that would allow its practical application.

At least, these negative findings will allow to evade mistakes of interpretation, which would be committed, when we made our estimates according to the first visual impression.

Drops falling vertically onto
an oblique target.
The shape of a blood stain as a function
of the impact angle.

In reality it more often happens, that drops fall onto a target obliquely, under a sharp impact angle. We have let drops fall onto angular targets of different degrees of inclination with respect to the horizontal position.
(Fig. 6, 7, 8, 9, 10, 11, 12, 13).

The shape of a stain depends in first place upon the impact angle. The shape is very little influenced by the dropping distance, what can be easily verified with the figures, for the construction of which four different dropping distances were choosen (1, 2, 3, and 5,50 meters). The shape depends also very little upon the drop volume, what we pro-ved with a practical experiment, letting drops of different volumes drip from a rabbits wound.

Thus, the shape of the stain is an element from which we can estimate the impact angle, the dropping distance and the volume of the drop.

The shape of a stain is such a remarkable feature, that with little experience it is possible to estimate the impact angle. But we require a still greater accuracy. We defined therefore the stains according to the relationship between their length and width. The sharper the impact angle is, the greater the difficulty to calculate its impact angle, because stains from sharp impact angles have their lower ends not clearly defined. The length of some stains cannot be measured, especially , when the drops fell from great heights. (Here comes up a new problem, which will be elaborated later).

After a series of numerous calculations we arrived at the point, to be able to calculate all angles. On the absciss the impact angles are marked, and on the ordinate the length to width ratios (Fig. 14). This curve was constructed by using blood drops of constant volumes, as in the construction of curve No. 1, because we wanted to achieve the highest possible accuracy in determining this new law of physics.

In this manner we were able to construct a useful curve. We stated also, that a similiar curve can be constructed by using fresh blood of different volumes, dripping out of a wound.

In the practical work it should not be looked after an illusionary accuracy. The measurement of stains with irregular lower ends causes difficulties of interpretation. In our experiments we couldn't determine the impact angles accurately, but only approximately. Nevertheless, this curve permits to estimate the impact angle with an acceptable accuracy, sufficient for practical purposes. Its indicatory value can be recognized, when regarding the hyperbola. For an impact angle of 90° (vertical impact onto horizontal target), the length to width ratio is 1, because the stain is round. For an angle of 0° , that means for a drop that would roll parallel to the targets surface, the ratio would be infinite.

It should be further noticed, that a drop striking a target in a sharp angle, causes secondary spatter, as it is also the case, when a drop falls onto a horizontal target. The shapes of these secondary spatter will not be the same as the shape of the main drop, because they have different impact angles. The prolongation lines of the longitudinal axes of these small secondary spatter converge in one point on the target, that is there, where the main stain is.

Estimation of dropping distances for drops,
falling from different heights
onto oblique targets.

The shape of a blood stain, that is its length to width ratio, depends very little upon the falling distance. But the falling distance influences the aspect of the lower end of the stain. First we examined stains, deriving from large impact angles (60, 45, 30 degrees). Drops of fresh blood from a wound caused nacelle-shaped staines when falling short distances. When the falling distances were bigger, on the lower end of the stains appered streaks (Fig. 15, 16, 17).

We tried to find out, whether it were possible to utilise this fact practically. In order to do that, we had to find out, what else, except the dropping distance, influences the changes at the lower end of the stains. We considered:
a) the drops volume;
b) the impact angle;

We made these experiments with blood rendered incoagulable, dripped from different pipettes, of 2/10 up to 9 mm of diametre. So we got very small and very large drops; in each test series the volumes were kept constantly. So we found out for each drop size the falling distance, where the changes at the lower end of the stains began to occur.

The curves in figure 18 explain the results. Each curve corresponds to another drop volume, which for each curve is constant.

The impact angles of drops are marked on the abscisse. The dropping distances, corresponding to those volumes of drops at which they started to form streaks and secondary spatter at their lower ends, were marked on the ordinate. These experimants proved, that the drop volumes scarcely had any influence upon the forming of secondary spatter and streaks, as long as the impact angles were large; but the influence of the drop volumes becomes significant, when the impact angles are small. We found, that for a 30° impact angle the dropping distance causing changes at the lower end of the stain.

Consequently we have found a rule, which can be applied in forensic medicine:

"A blood drop, falling vertically onto an oblique target under a greater impact angle than 50° and which causes a stain with a nacelle-shaped lower end, without streaks and secondary spatter, fell probably from not more than 50 cm hight."

This rule means a limit for the dropping distances. We have checked this accurately with drops falling vertically onto oblique targets. It can be assumed, that the rule applies also in those instances, when drops are falling obliquely onto horizontally or obliquely positioned targets, as this is mostly the fact in the forensic practice. But before we can confirm this assumption, more experiments will be required.

Please note, that our curve touches the 90 degree point, in the coordinate system. With our experiments we confirmed, from which dropping distances drops falling vertically onto a horizontal target, produce stains with spines. Further we found theoretically that moment from which on, at the lower end of the stains several droplets,instead of one only, appear. Furthermore we found that moment, from which on no more round stains are produced, but such with spines around (vertical fall onto a horizontal target). In tests this moment of change was found for dropping distances less than 25 cm.

For reasons we can't explain yet, these findings can not be applied in forensic medicine. We have already before pointed to Figure No. 5. There are reproduced two staines deriving from two drops, which fell from the same height of 5,60 meters. But on the smaller stain there are even under a binocular loupe, no spines detected. Don't they really exist, or aren't they just visible because dried blood forms scales ?
It is a fact, that up to now it is not possible to estimate the falling distance of a vertically fallen drop, which caused a stain on a horizontal target. But when the drop fell onto a slightly oblique target, we can estimate approximately, whether its falling distance was more, or less, than 50 cm.

The blood crust in the lower portion of the stain; Its significance for the determination of falling distances.

We resume again the examination of drops falling onto an oblique target. We find, that these stains are not homogeneous (Fig.19, 20). The upper part is reddish (or brown in elder stains), the lower part is dark, nearly black, because of the crust in the lower portion. Between these two parts, there is a clean strip. Blood, accumulated in the lower portion of the stain covered initially also this clear strip. But later the blood contracted, or rolled down, leaving over that clear strip..

Further we noticed, that this lower dark portion is bigger, when the drop causing it, fell from a low altitude; conversely it becomes smaller, as the falling distance of the drop causing it, becomes bigger. This can well be recognized in picture 19, where strong contrast for fotography has been used.

Maybe this will constitute a feature enabling us to determine the falling distance ? This feature we assumed in the relationship:

$$\frac{\text{total length of stain}}{\text{length of its lower portion}}$$

and we decided to include, as part of the lower portion, also the clear strip. When the lower portion is very small it is more convenient to measure the upper part and the total length. The difference then will constitute the length of the lower portion.

We have examined this relationship at different falling distances and at different impact angles, and we used only drops of fresh blood from the wound of the rabbit. Uncoagulable blood, which is necessary to work with constant volumes does not produce this sort of stains, because the aspect of the lower portion is caused by coagulation.

The vurves in the figures 21, 22 and 23 show the results. The falling distances are marked on the abscisse, the upper to lower portion ratios, on the ordinate.

We stated, that this ratio becomes bigger, as the falling distance becomes bigger, but it also depends upon the impact angle. The sharper the impact angle, the bigger the ratio. So we found, that with an impact angle of 60 degrees and a falling distance of 20 cm the ratio was 1,3. With the same impact angle, but from a falling distance of 200 cm, the ratio was 2,3. With an impact angle of 50 degrees and a falling distance of 20 cm the ratio was 1,6 but it was already 3 at a falling distance of 200 cm. When the impact angle was 30 degrees, the ratio climbed up to 2,3 at a falling distance of 20 cm, and up to 4,5 at a falling distance of 200 cm.

What is important to us in the forensic medicine is the degree of exactness of conclusions we can draw from these results in a real criminal case. The graphs show distinct regularities for impact angles of 50 and 60 degrees. But they show also a number of measurements deviating from the average. For impact angles of 30 degrees, these graphs are useless, because there we find ratios of 3,5 at falling distances of about 20 cm, as well as of 250 cm.

The overall impression is, that a regularity exists in so far, that the ratio is augmenting in as much as the falling distance is rising, This relationship is, generally speaking, not distinct in the case of sharp angles and its application to the real case is disturbed by other factors too, probably in first place by the drop volumes.

We found further, that in the case of small stains, the ratio was small also when the falling distance was high. Summing it up, we state: these ratios are from a practical viewpoint of no avail, except for the case with large impact angles, because then a small ratio indicates, that the drop did not fall from very high.

After all it seems to us, that this feature is not an as distinct one, as the nacelle-shaped lower end, provided, that further examinations which will be conducted, will not proeve something else.

Other shapes of staines.
Pen- and spindle shaped.

Up to now we worked on shapes of staines which occured under larger than 30 degrees impact angles. But when blood falls onto a target under a more acute angle, other features appear.

Let's have another look on figure 12 (impact angle of 15 degrees) and on figure 13 (impact angle of 5 degrees). Both were produced by drops of fresh blood from a rabbits wound and they fell from different distances onto the target. Within the lower part of the stain we see empty spaces between streks, so as if somebody wrote with ink and a metal pen, but pressed the pen too hard to the writing pad, so that the two halfs of the split metal tip bent apart, causing two diverging lines. These pen-shape patterns are the more accentuated, the more acute the impact angle is. This configuration looks clean at an impact angle of 15 degrees (Fig. 12), but it seems exaggerated at 5 degrees (Fig. 13).

Probably the pen-shaped configurations occur only from a certain falling distance on, because we missed them in our experiments at falling distances of less than one meter. Possibly we found here a feature, by which we can estimate impact angles of less than 30 degrees, similiarly like it was possible to estimate impact angles of more than 50 degrees by the nacelle-shaped lower parts of stains and by the secondary spatter.

Here we see still more details. On the above mentioned figures we see, that at the lower end lines descend, wich still further downward unite again, cross one the other or interweave (Fig. 24). The configurations at the lower end finally change that much, that fuse-like appendices appear, long drawn out downwards completely unlike the nacelle-shaped end. (Fig. 25). Sometimes rosary-shaped or quill-shaped stains appear (Fig.26), because in the case of a very sharp impact angle, the drop is rebounded, slightly displaced and rolling further along oh the targets surface.

Before we start drawing conclusions from this for our practical work, it seemed logical to find the reasons, which caused these peculiar shapes. We wanted to learn, how stains generally are being shaped, whilst they occur.
In order to understand that, we applied cinematographic examination methods.

Cinematographic examination of the development of a stain.

These examinations took place in the Marey Institute with the kind support of Mr. Bull and Mr. Nogues. The technique itself is difficult and we are still far away from our goal.

They offered us two recording systems. One, consisting of a usual movie recorder, adopted by Mr. Nogues for special purposes, was suitable for 200 - 250 pictures per second. The film was supplied from a roll and could be very long. It worked with wide-angle lenses. We tried our experiments with this apparatus, but it appeared to be insufficient, because the features we wanted to register, are occuring too fast.

The escond apparatus was supplied by Mr. Bull. It permitted 500, 1000 and even 2000 pictures per second. The flash lights were regulated by an electro-magnetic intermitting device.

We had to fotograph the stains on a transparent target. But, as it will be explained later, on a glass panel special shapes of stains uccur due to the high viscosity of blood and its weak adhesive ability to glass. We had to find a target as transparent as glass on which the stains would be shaped as on cardboard in order to examine here too, the usual stain patterns, as previously on cardboard. We ehoose debrominated film material. This is transparent and simultaneously rough, so that the stain sticks to its surface as it does to cardboard.

Another difficulty posed the fact, that it was technically impossible to run down a single film on a speed of 500 or 1000 pictures per second without interruption. So we attached a film strip on the outer circumference of a big roll, so that the total length of the film strip was equal to the circumference of that roll. This roll we turned rapidly and the fotographs were made only during this single turn of the roll. But thus we could make only 50 fotographs, , so that at the speed of 500 fotographs per second, the ectual exposure time was only one tenth (1/10) of a second.

Because the examined phenomenons occur very fast, so that the speed of 500 pictures per second was necessary, but the total occurance lasted longer than one tenth (1/10) of a second, we were not in a position to document the whole procedure on one single film strip. We had to run it through several times.

Another difficulty was, that the roll with the film strip had to start the run, each time, at a very precise moment. Because the apparatus worked with a narrow angle lense, we could not experiment with fresh blood from the rabbits wound. Therefore we used a colored fluid (water with saffron), applying it from a pipette so as to regulate the dripping according to necessity.

Our first tests were interesting and we hope to get more useful knowledge when the work on this subject will be continued.

How the quill-shaped stains may occur, it was explained to us by Mr. Foch, who employed a hypothesis. He explained, that in order to find in physics a solution it is necessary to start from a hypothesis similiarly like the physician starts from the pathogenesis. Both, if right, have finally to be confirmed by experience.

A flying drop through the air, he explained, is more or less ovoid and when touching down on the target, it touches first with a small fraction of its outer surface. In this tangential point the drop is slowed down. This slowed down portion of the drop creates the center of the stain. The other parts of the drop, which are further away from this tangential point of first contact, the fringes of the drop, they still have a higher velocity and they touch the surface of the target a bit later and further down.

Figure 27 shows a drop being projected onto a target from 80 cm hight, under a 20 degree impact angle.

The first fotograph shows the drop still in the air. It is not ovoid. But we know, that the shape of a drop changes during the flight.

The moment it touches the target, its width is increasing, it proceeds along the target downward, still further increasing its width. It attains its maximal width after 1/250 of a second. We notice, that the fluid now is assembling mostly at the rim and in the lower part of the drop. Here in the lower part a huge ovoid mass is being formed, which flows further down, loosing substance, until, approximatele 1/100 of a second after the drop touched the target, its substance is used up.

At this moment the fluid substance is accumulated predominantly at the rim of the stain. Its center is very clear, but covered with waves.

The low edge still proceeds descending and by this the stain continues to elongate downwards. It finally breaks up into several sharp pointed streaks; some of them will intertwine a bit further down.

Meanwhile the waves inside have become bigger in size but decreased in numbers. It can be noted clearly, that then the rim is broadening, thus causing the inner edges of the rim to move closer together. This terminates the development of the stain.

We could not confirm the assumption, that the speed of movement at the rim was greater. But we confirm, that the center of the stain is developing later than the rim and that this is due to reflux of fluid.

Apart from that and in addition to the waves, in the upper third of the stain there appeares an accumulation of fluid in the form of a tiny, black looking dot, which seems to remain stationary. We have fotographed this phenomenon not only from the top, but also from the side view. We noticed, that the stain flattened very soon. 3/500 of a second after the drop touched the target no further changes can be registered from the side view by fotography.

The previously described though is not all yet. 27/500 of a second after the first touch down of the drop onto the target, considering our working conditions, we have always detected a small, additional drop (Fig. 28, and 29)

It develops at the upper rim of the stain either in its middle line or slightly shifted sidewards and it accentuates in a certain manner the clear center of the stain by shading it. The secondary waves also develop under its influence. Furthermore, this secondary agglomeration also has its clear center and a rim.

When a drop falls down from very high, then this additional drop frequently falls beside the main stain and then it is visible also without cinematography. We believe, that this additional drop develops, when we produced drops with a pipette. We did not notice it, when blood dripped out of a rabbits wound, but at present we can't yet say about this anything definitely, because, blood drops often accumulate at the end of the tiny hairs of the rabbits foot. From there tiny droplets fall off and they may be confused with the additional drop.

All this prooves, that the act of development of a stain is some special, complex occurance. The exact steps in this development of the stain we will be able to examine only, by using cinematographic methods on different fluids, taking always into consideration the viscosity, osmotic pressure and other features of each sort of fluid.

The depressed center of the stain.

Our cinematographic examinations proved, that when a stain develops, the fluid is not equally distributed. When looking at a stain with a binocular loupe, the center appeares clearer than the rim. When the stain derives from blood, another feature comes into focus: the coagulation. Coagulation goes hand in hand with retraction.

Furthermore, the outer appearance of the stain changes by drying and as a result of forming scales. The overall view under the binocular loupe shows empty spaces inside the stain and depressions in its body. We have to stress this fact, because when this is wrong interpreted it may evoke serious mistakes.

The assumption prevails, that spitted blood deriving from the respiratory organs is permeated by small bulbs of air, leaving recognizable traces in the dried blood stain so that certain features of the dried blood stain allow to recognize, if it was caused by blood from the lungs.

A glance at the pictures No. 30, 31, 32 and 33 is sufficient in order to understand, how cautious we have to be before saying anything about the origines of a blood stain. These here are microfotographs of blood stains deriving from drops out of a rabbits bleeding wound. Their outwardly aspect is different, most probably because they belong to different stages of the same process.

Picture 30 shows a stain with a clear center and with a dark ring in its middle portion. That's where most of the blood is collected; the dark ring again, is itself surrounded by a bright rim.

In the picture 31 blood is collected in the middle zone having a depressed center of a kind, which appeares on the microscopic fotograph as a very big, red ball.

In picture 31 there is no blood at all visible in the center. Under a binocular loupe the center looks like a crater. On the microfotograph are here shining points visible, looking like blinking spines of a crown, being nothing else, than artifacts of illumination.

Finally, in picture 33 there is visible something like a bridge over the center, from one side of the brim to the other, making the whole structure look like a basket with handle.

The mechanism, how these structures are created, we couldn't fully understand. Are they droplets of blood, with air pockets inside ? Or do they appear as a byproduct of coagulation and retraction ? We suppose, the latter assumption is right.

We have noticed these structures in very small stains only, deriving from very small, but full, thick and round droplets, which often were secondary spatter ejected from the main drop.

Definitely we can say: they did not come from the respiratory organs.

Trajectories of blood drops.
Finding the height of the ejection point.

Up to know we have talked only about stains and their shapes, when they occured as a result of vertical falling onto an oblique target. Practically though, it is mostly that way, that that blood drops are ejected from a wound and arrive along trajectories on a horizontal (ground) or vertical (wall) target. Even if the stains are situated on various levels, it is by means of geometrical construction possible - ofted with great accuracy - to find out the ejection point in the room, from which the blood came from. That is the usual task.

We posed therefore the question:

> Is it possible to find that point in the room, from which the blood spattered away, when the stains are situated on one level of the target ?

If we find blood stains on a wall, we recognize that the vertical altitude where the spatter are, seldom is the same altitude at which the blood spatter were ejected. Blood drops, being ejected from the same impact point constitute usually a bunch of trajectories. These trajectories end up one after the other at different points on the wall and form there an arc.

Let's leave now this somewhat complicated problem away, and let's look at the horizontal plane. The problem then looks like that:

On the ground (Fig.34) we found stains at the impact points P, P', P". The extensions of the longitudinal axes of these stains converge in point "A". Blood spatter consequently, being ejected from point "X", being situated on the vertical line "AB", but above the point "A". How can we find out the difference in height between "A" and "X" ? - The shapes of the stains at the impact sites P, P', P" are the result of the impact angles a, a', a", These angles can be calculated as width to length ratios, how we have shown this previously.

Up to now we defined this law only for the simple situation, when the drop fell vertically onto an oblique target. Now we have to find out, whether this law permits also to calculate the angle of the tangential line touching the trajectory in its point of contact with the target and if this calculation can yield accurate, or only approximate results. To visualize the necessary examinations we made fotographs of the following trajectories:

We know the point "A" and the angles a, a′ a". Furthermore we don't consider the force with which the drop was ejected from point "X": we just know, that not all drops are ejected with the same force. Although they all come from the same point, not all of them atteined the same distance from it, because not all had the same speed at the beginning or at the end of the trajectory, or they didn't have the equal volumes.

It is extremely difficult to answer this question. We just are working on it in order to find out the way, in the following manner:

No bunch of trajectories, ejected from another ejection point as "X" on the vertical line "AB" can create the angles a, a′, a" at the impact points P, P′, P".

Were the drops for instance ejected from point "Y" (Fig. 36) than the same curves of the trajectories arriving in P, P′, P", would be more flattened and the impact angles sharper: b, b′, b" .

If they were ejected from "Z", the impact angles would be accordingly bigger, corresponding to g, g′, g".

It is sufficient to get to know the bunches of trajectories leaving the ejection points X, Y, Z. We confirmed this by examining the jet. Picture 37 for instance shows the real trajectories leaving the same ejection point at the height of 30 cm above the ground. The fotographs were made from a distance of 3,50 meters. The impact angles can be exactly measured with the protractor. The marks on the fotographs indicate the distances of the different jets. We didn't have strong enough light, to fotograph trajectories of real blood drops. We helped ourselves with water jets. Mr.Degan was so kind to help us with his facilities.

A sufficiently great number of fotographs has put us into the position to confirm beyond any doubts, by means of graphs or simple mathematical calculations, that the series of angles a, a′, a", being at places in the distances A-P, A-P′, A-P", coming from the ejection point "X", really came from this point "X" and not from point "Y" (from which the angles would have been b, b′, b"), and also not from "Z" (from which the angles would have been g, g′, g").

This would be the way to solve these problems, if there wouldn't be another onknown to us factor. Up to now we have made our deliberations as if we knew the angle of ejection of the drops. In reality we didn't consider it so far. Really blood could have been ejected in the ejection point horizontally or obliquely (Fig. 38) so that the angles of the stains a, a′, a" in the impact points P, P`, P", could derive from drops being ejected in any way.

We shouldn't forget though, that we already have found, that under certain conditions we could verify by means of the nacelle-shaped lower end of stains, or by the streaks at their lower ends, whether a stain came from above or from below a certain level or point in the room.

Now, it is possible that these additional considerations will contribute in so far to our ability to solve a certain practical problem, that we will be able to reject certain notions, which may occur to us after the first glance as a solution. Practically these methods can anyway only in a very limited way be applied. Sometimes it is necessary to find out, whether a victim, at the moment he was injured, stood on his feet, or was lying. Only practical tests will show, whether the real problem can be solved.

Now, since we have worked out the principles, we believe, that more examinations should be conducted, despite the difficulties the problems pose.

Changes in the shapes of stains depending on the nature of the target.

The shape of the target .

The surface on which a stain is shaped is not always flat. It is interesting to know - we will later show an example for it - how a drop is being disfigured, when it falls onto a round target. We let drops fall onto a cylinder and we found:

1.: Is the axis of the cylinder horizontally positioned, the stain will not be extremely disfigured when the drop falls right onto the cresting line. The liquid then equally divides up and flows down both sides symmetrically. When straightening afterwards the bent of the cylinder, it can be seen, that the stains seem extended sidewise. But when the drop falls to one side of the cylinder, below the cresting line, the stain just elongates.

2.: When the axis of the cylinder is positioned obliquely, things are more complicated. Picture 39 shows the aspects of two stains after the cylinder was straightened. They were produced by two drops of the same volume each, which fell onto the same cylinder of 8 mm diameter with 45 degrees obliquity of the cylinders axis, arriving at two different points on the cylinders side, one 39 mm, the other 25 mm below the cresting line (measurements made at the outer circumference).

It can be seen clearly, that the edges of these stains are shaped unequally because the main axes of the stains do not have the same direction as the main axis of the cylinder. That's anyway the main reason. The shape of stains thus is influenced by many factors.

The nature of the target,
textiles, and others.

All experiments we did so far, were performed on cardboard. It seems necessary to find out, how and up to what extent, the outwardly aspect of stains changes, when the drop falls onto a target made of some other substance than cardboard.

We let drops fall vertically, as well as under the impact angle of 45 degrees onto different substances, like tiles, parquetry, textiles, furs, metal, and blotter and we found, that the outwardly aspect of a stain can alter significantly. We will now try to classify these deformations; they can be caused by:

1.:
The target has no adhesive property so that it compells the fluid to retract -
here belong slightly fattened tiles and glassware (Fig.40).
A drop of fluid extends on such a target initially normally, but immediately, few moments later, it retracts (sometimes unsymetrically), and a stain appears with a round or irregular brim, which corresponds to the initial extension of the stain, as it can be recognized on the fotograph.
On well cleaned chinaware and clean glasware or on untreated oak, we did not observe retraction.
On rubber the stain may divide up (Fig. 41). This can be seen on textiles which are impregnated against rain (raincoats).
Similiarly it is the case with mousseline of cotton, but with the little difference, that the fluid, after initial retraction, expands again, penetrating the surrounding fibres. (Fig. 42).

2.:
Furthermore, the deformations can be caused when textiles are wet, or by lack of expansion -
picture 43 shows stains, which were caused by two drops of the same volume, fallen from the same height of 1 meter, but impacting different sorts of textiles: cotton veil and felt.

On cotton veil the stain expanded and penetrated with moist the fibres. On felt it did not expand, because the thick canopy of fibres prevented this. Small, secondary droplets couldn't penetrate at all and were caught on the surface endings of the fibres.
With all felt-like textiles and with fures it is similiar. Blood cannot penetrate despite the impact of the drops, the stains remain small and form crusts.
Therefore there are blood stains of different size, depending, whether the textile is absorbtive, or not.
Textiles with a tram in the fabric can cause unevenly penetration by fluids in a double sense. Looking at blotter, this can be easily understood. If you touch with ink and a pen on blotter, the dot will not become round, but oval. The same applies to some sorts of textiles. Picture 44 shows two stains from blood drops of the same volume, which fell onto the same sort of textile("peau d'ange")from the height of 1 meter. But the length to width ratios for both of them are not equal. Would we apply in this case blindly this law, we would have calculated different impact angles, for the one more than 45 degrees, for the other less.
This, because the tram in the texture doesn't have the same direction. The imbibition is asymetric so that one stain was alongated, the other broadened.

3.:
Furthermore the deformations may be caused by granular or sticky surfaces -
the surface of some couloured prints is very little adhesive what favoures retraction. But the stains become asymmetric because of the granular structure of the surface (Fig.45,46) or the stains assume peculiar, arched forms (Fig.47).
First we conducted our experiments with known volumes of uncoagulated blood in order to get comparable results.
Later we found out, that fresh blood from a rabbits wound creates the same traces.
Arched configurations can be found too on rubber (Fig.48), on timber and generally on all uneven surfaces.

4.:

Furthermore the deformation can be caused by some additional written sign on paper or by a hole in the textile - an additionally made written mark with pen and ink, or with some colour on paper, will partially obstruct the expansion of the stain. Similiarly acts a hole in the fabric. According to the circumstances the stain may seem as if amputated (cut-off), without having changed the shape from normal in the not amputated parts. (Fig. 49, 50).

5.:

Furthermore the deformation can be caused by oxidation of the target -

sometimes it is easy to confuse it with retraction, when a later reaction between the bloodstain and the target react with each other.chemically. On picture 51.we see the blood stain surrounded by an uneven brim. The target is here a piece of zinc on which several days after staining a bright rim occured around the stain with an uneven edge. This is a case of pseudo-retraction.

Summing up, we can say, that we distinguish the following deformations:

retraction, enlargement, diminishing, misshaping and amputation .

These modifications are sometimes obvious. But we have to remember constantly, that also on an apparently homogeneous target uneven ares can occur which may cause slight disfigurations to stains.

The following conclusions are to be drawn:

Before somebody starts to interpret stains and their shapes, he has to examine the nature of the target. The graphs we worked out are valid only for those targets, we have used during experiments and that was cardboard "Rigidex". If one has to make an expertise he has to examine first the target on which the stain is. The methods are already known, and their application shouldn't cause any difficulties.

Blood from cadavers.
Serum spatter.

It is important to distinguish, whether blood to be examined derives from a living or a dead person. We have previously pointed out, that bloodstains from blood rendered uncoagulable, and such dripping from the wound of a living rabbit, have different features. We believe, that when careful examinations are done it can be distinguished also between coagulated blood and blood from a cadaver; but to this point our experiments so far were superficially only.

We now will restrict ourselves to point out one very important feature:
Sometimes, only serum staines, but no blood stains, can be found. Picture 52 shows the aspect of a stain, which was produced in the following manner:
A rabbit was wounded, then put by anaesthesia to sleep and it remained motionless until its death. From its wound first blood was dripping, creating a pool of blood and that coagulated. When further drops fell onto the pool, they caused dark, secondary spatter producing dark stains (in the picture the nacelle-shapes are seen few centimeters from the edge of the pool).
Then the rabbit died. At its wound blood coagulated and after that only serum was dripping, the color of which became brighter and brighter, and they carved a hollow impression into the coagulated pool of blood, ejecting yellowish, amber secondary spatter (Fig. 52). These spatter were very distinct in color from the blood spatter.

We repeated the test several times. The result was not always the same. Maybe in the wounds of living organisms different processes take place. However, in each case of a blood pool showing similiar features it is possible to recognize, whether the wounded victim was for a long time motionless lying in that place, in other words, it is possible to estimate the time-lapse necessary, until serum instead of blood started dripping from the wound.

Picture 53 shows another interesting feature. An object fell onto a pool of coagulated blood, some time after the coagulation. The spatter occuring due to the impact of the object were serum spatter. These amber stains differed markedly from the dark blood stains. This proved, that a certain time - at least so much as was necessary for the blood to coagulate - had to elapse, between the coagulation and the moment, the object fell into the pool of blood. This observation can be important for the reconstruction of what happened at a crime scene.

This, however, we couldn't reproduce regularly, The lack of occurance of these features, consequently doesn't mean, that an object found in a pool of blood, was there from the beginning of events.

Drops of other fluids,
not from blood.

Some nuances of the aspect of stains depend upon the type of fluid causing the stain, but in general, the shapes of stains are the same, no matter by what sort of fluid they are produced. The decicive feature determining the shape of a stain is the way, how the fluid comes into contact with the target.

So stains of ink, or stains from spilled wine, may give useful hints as to what happened.

Frequently it occurs, that a car is losing oil. The degree of the impact angles indicates the actual speed of the car. We proved experimentally, that by verifying the changes in shapes of oil stains it can be stated, where a car accellerated and where it slowed down.

The latter feature is indicated also by the number of oil stains at the different places.

Picture 54 shows superficial skin-bruises caused by drops of boiling oil. Because of the shape of the forearm the drops did not everywhere arrive on the skin under the same impact angle. The produced bruises are corresponding in shape to the impact angles at the different sections of the forearm. Some show distinct deformations due to the roundness of the forearm. (See also page 24 and Fig. 39).

Thus the usefulnes of the examination of shapes of stains on different targets is evident. In an expertise it could be required to tell, whether a fluid was gushed or spattered onto the victim from far, or from the near.

The examination of stains - and not only of blood stains - can deliver many valuable knowledge to the specialist in forensic medicine.

Final conclusions.

The outwardly aspect of stains from fluids, especially of bloodstains, can serve the specialist of forensic medicine with valuable information.

The different shapes, depending upon various factors, have to be examined very carefully, conducting the appropriate experiments, proceeding from simple to the more complicated tasks. This method we applied with great benefits for our understanding of facts.

Finally we wish to stress emphatically:

Our experiments and inve-stigations are not yet finished. The rules we established are valid only under those conditions, under which we were experimenting. Before we can generalize them, more detailed examinations have to be done.

The laws of hydrodynamics governing the shaping of stains are very precise, but also very difficult and the degree of the required certainty, especially in court matters, will not be available as long as all these laws and rules are not defined, one after the other, with the greatest possible exactness.

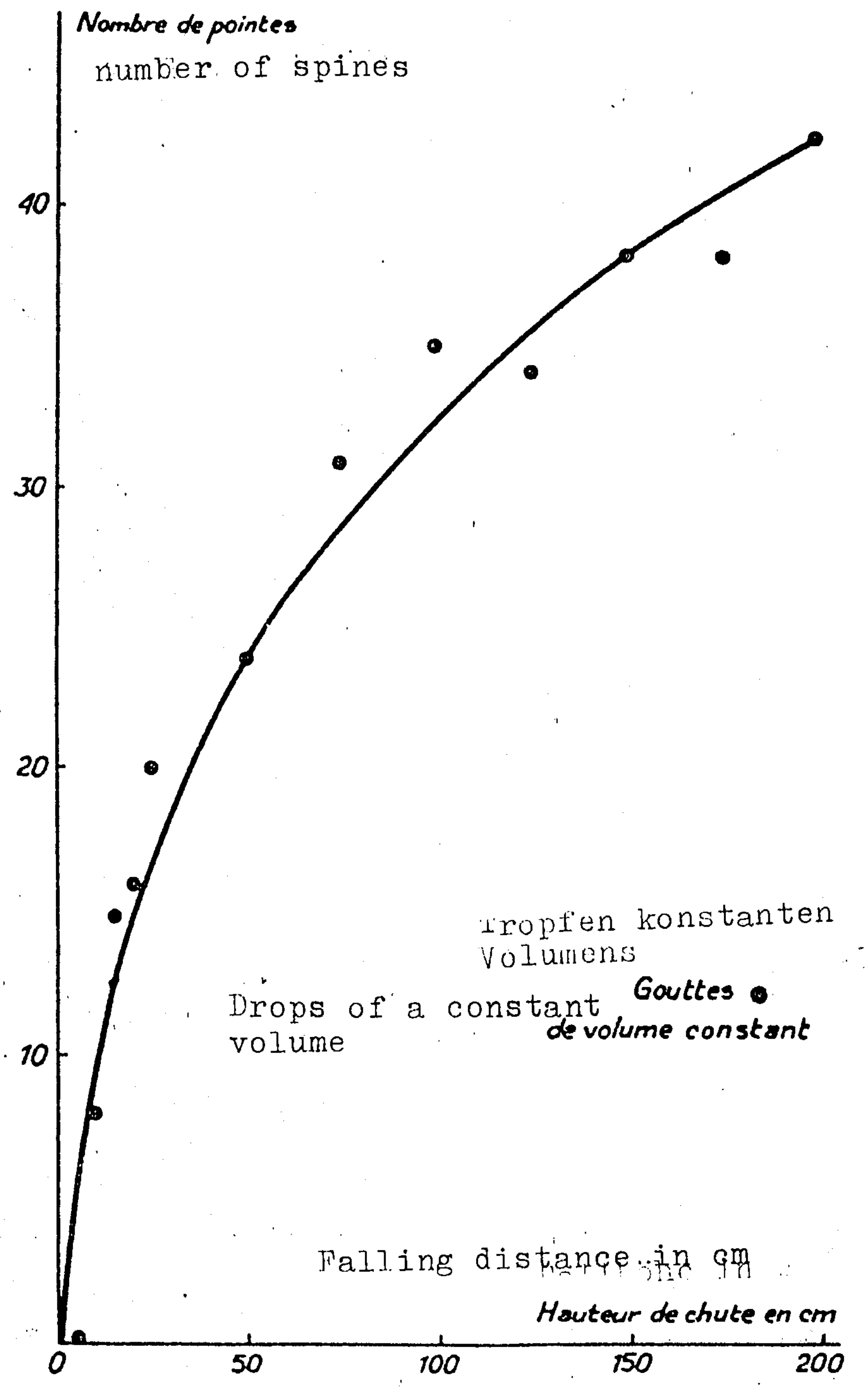


Fig. 1. — Nombre de pointes des taches suivant la hauteur de chute.

Fig.1 - Number of spines depending on the falling distance

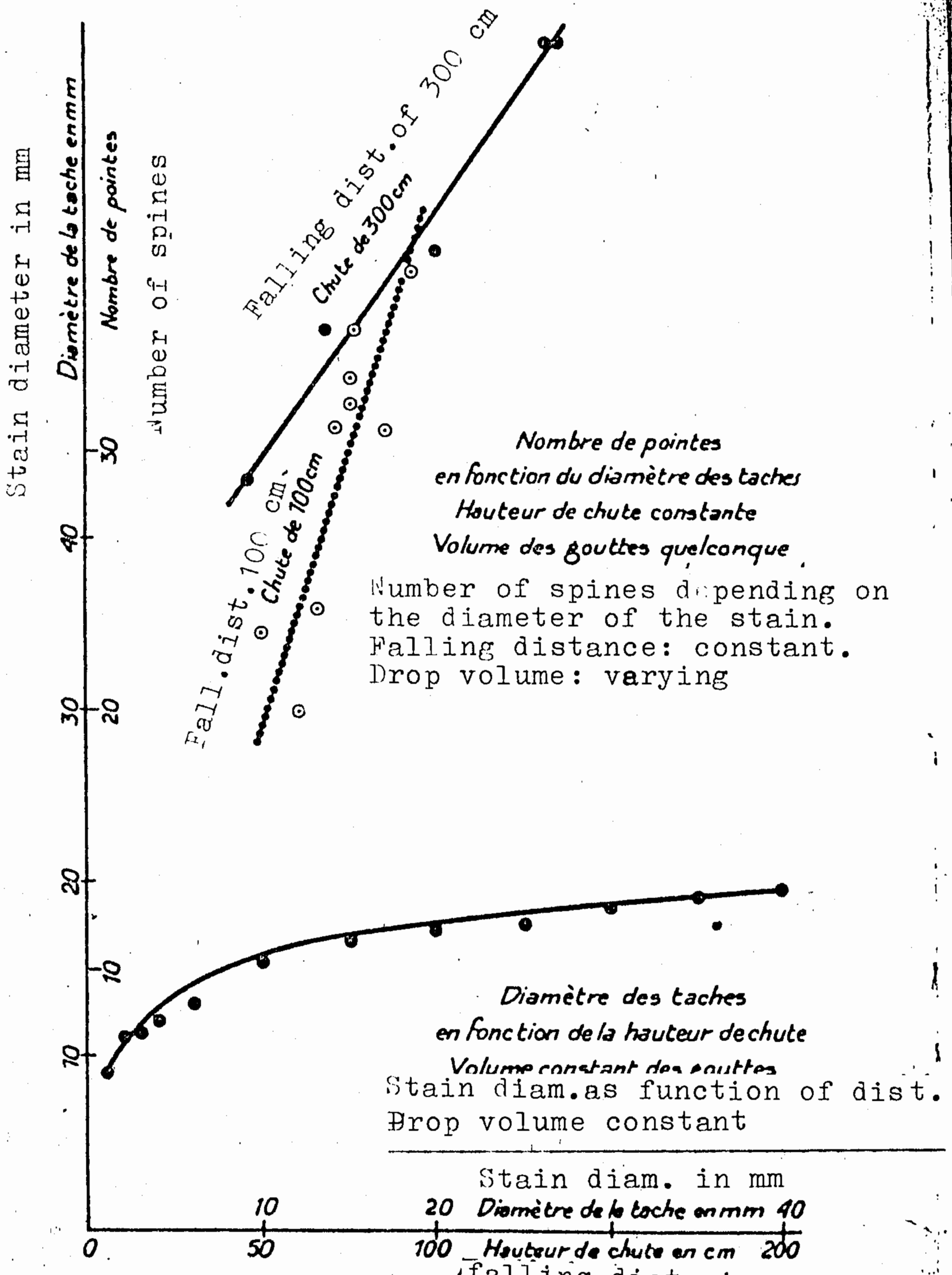


Fig. 2. — Comparaison de deux variables : qui déterminent le nombre de pointes des taches du sang.

Fig. 2: - Comparison of two variables: size of the drop and the falling hight, which determine the number of spines on the stains edge.

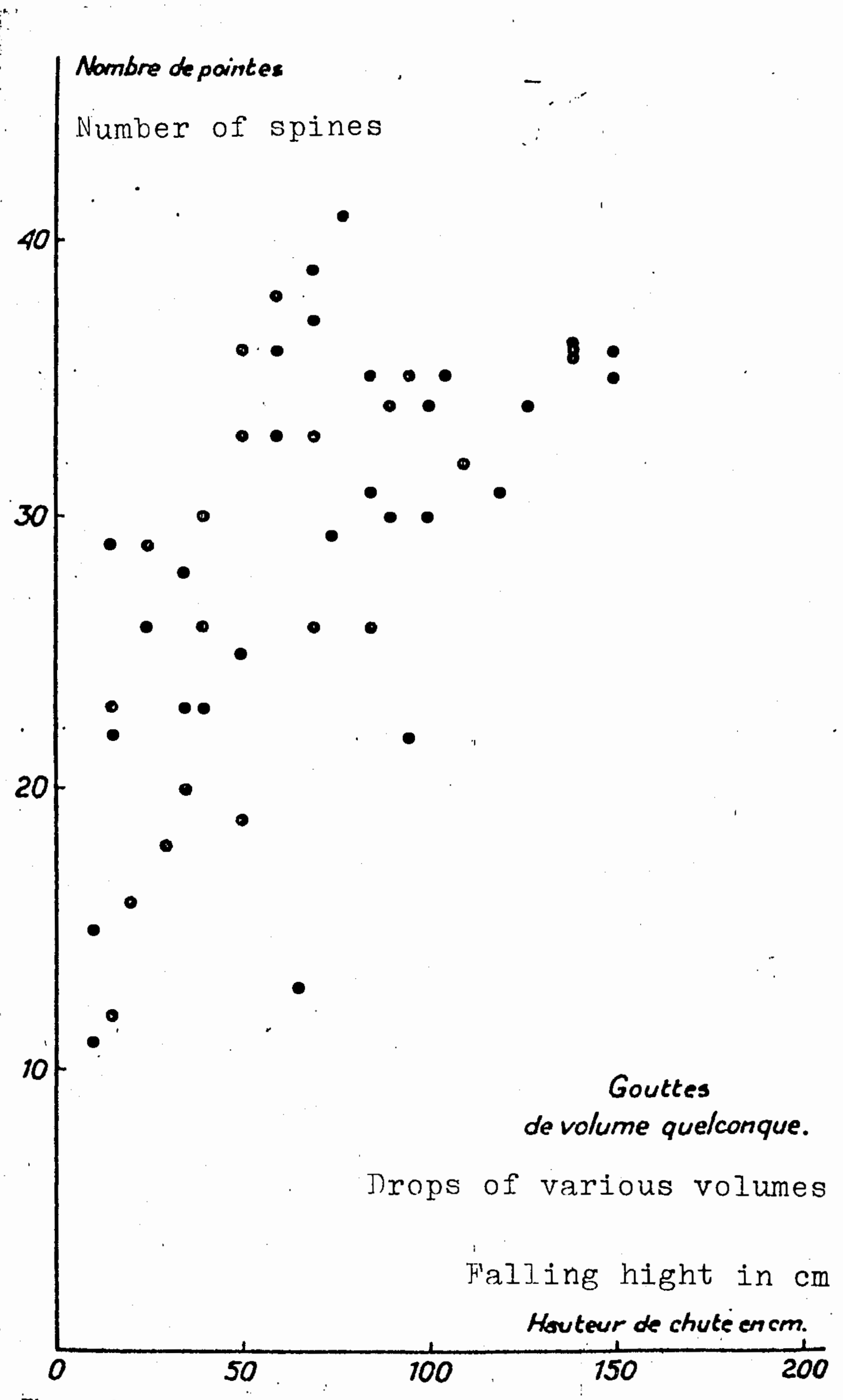


Fig. 3. — Lorsque les gouttes de sang ont un volume quelconque on ne peut pas, d'après le nombre de pointes des taches, dire de quelle hauteur sont tombées les gouttes qui ont formé ces taches.

Fig. 3 - When blood drops are of different unknown volumes it is not possible to estimate the hight of the falling distance of each stain, having for this estimation only the number of spines on the edge of each stain.

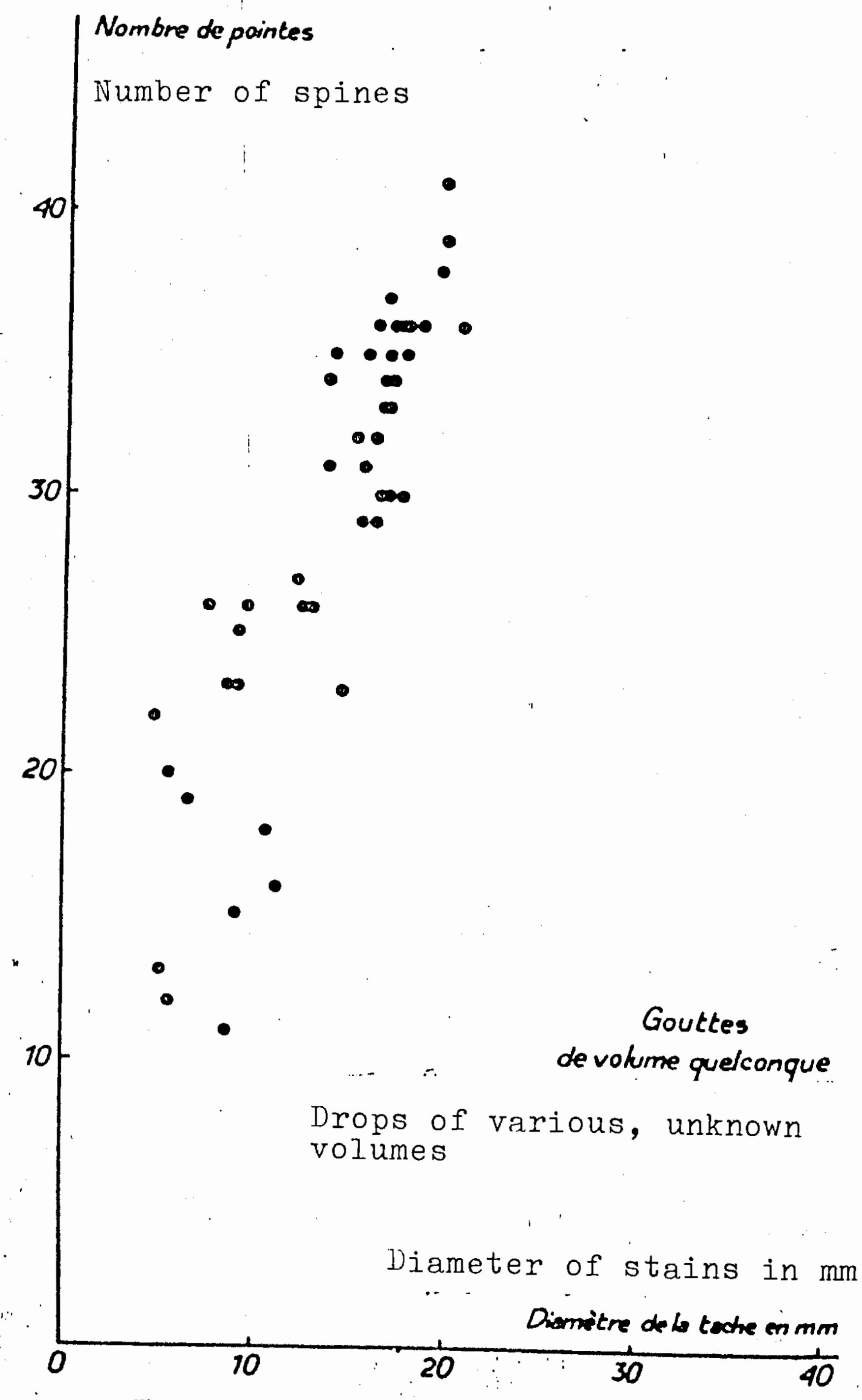


Fig. 4. — Le nombre de pointes des taches dépend avant tout du diamètre de la tache.

Fig. 4 - The number of spines at the staines edge depends in first line upon the diameter of the stain

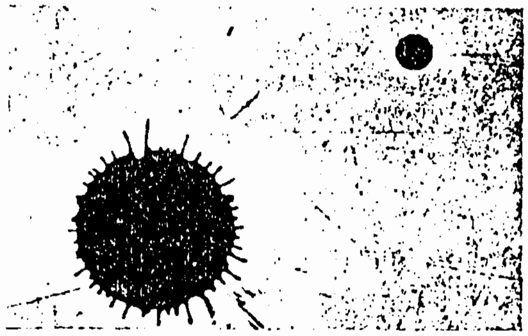


Fig. 5. — Deux taches provenant de deux gouttes tombées d'une même plaie sur un plan horizontal. Hauteur de chute : 5 m. 60. *Grandeur exacte.*

Fig. 5: - Two stains deriving from two blood drops which fell from the same wound onto a horizontal target. Falling hight: 5,60 meters
Real size.

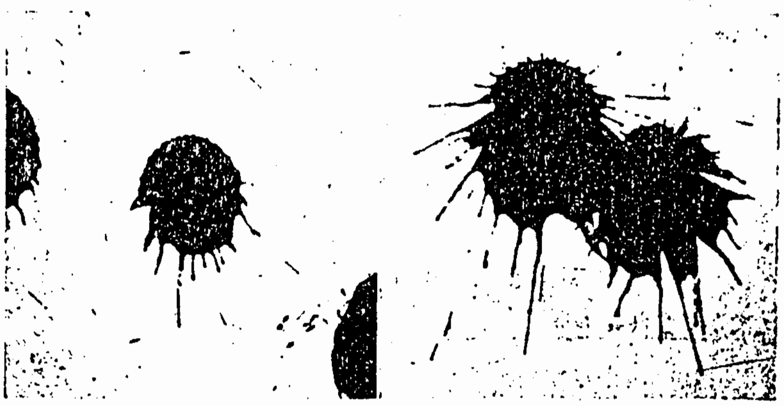
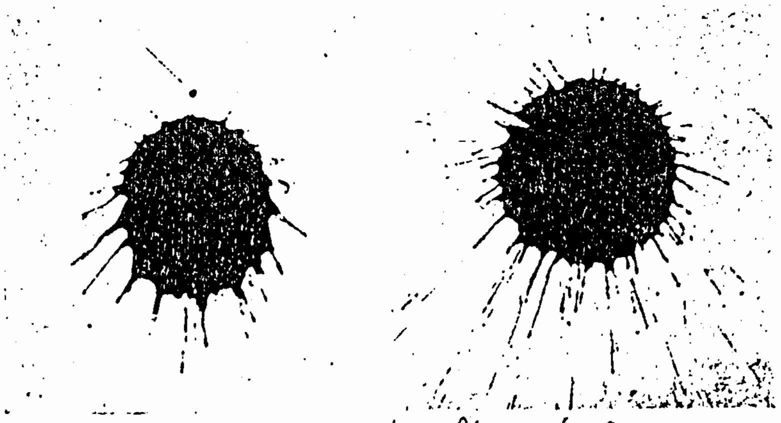


Fig. 6. — Angle d'arrivée : 60°. Hauteur de chute : 1 mètre, 2 mètre. *Grandeur exacte.*

Fig. 6: - Impact angle: 60°
Falling height: 1 and 2 meters
Real size.



Ankunftswinkel:
Fig. 7. — Angle d'arrivée : 60°.
Hauteur de chute : 3 mètres, 5 m. 50 environ. *Grandeur exacte.*

Fig. 7:- Impact angle: 60° , Falling distance 3 and 5,50 m.
Real size

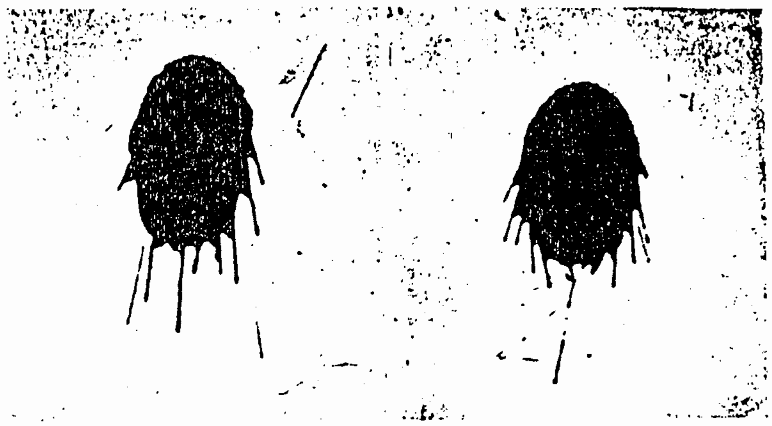


Fig. 8. — Angle d'arrivée : 45°. Ankunftswinkel,
Hauteur de chute : 1 mètre et 2 mètres. *Grandeur exacte.*

Fig. 8:- Impact angle: 45° , Falling distance 1 and 2 m.
Real size.

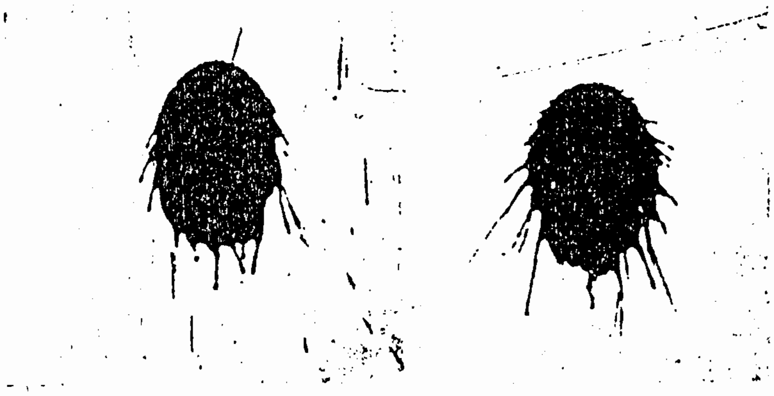


Fig. 9. — Angle d'arrivée : 45°.
Hauteur de chute : 3 mètres, 5 m. 50 environ. *Grandeur exacte.*

Fig. 9:- Impact angle: 45°, Falling distance 3 and 5,50 m.
Real size

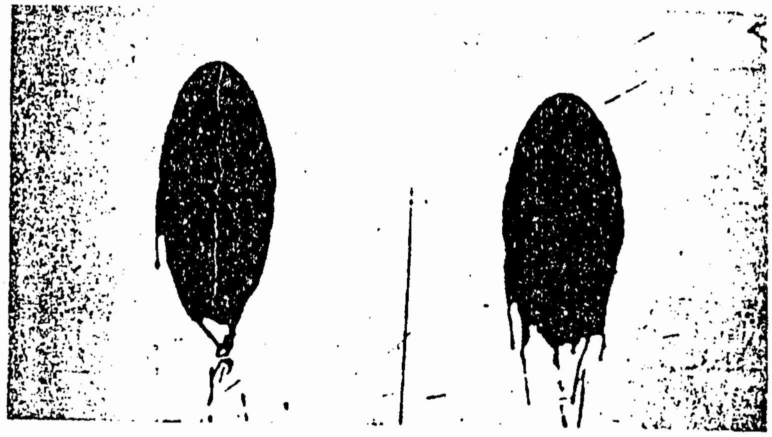


Fig. 10. — Angle d'arrivée : 30°.
Hauteur de chute : 1 mètre et 2 mètres. *Grandeur exacte.*

Fig. 10:- Impact angle: 30°, Falling height: 1 and 2 Metsrs
Real size

Fig. 11. — Angle d'arrivée : 30°.
Hauteur de chute : 3 mètres et 5 m. 50 environ. *Grandeur exacte.*

Fig. 11:- Impact angle: 30°, Falling height 3 and 3,50 m.
Real size.

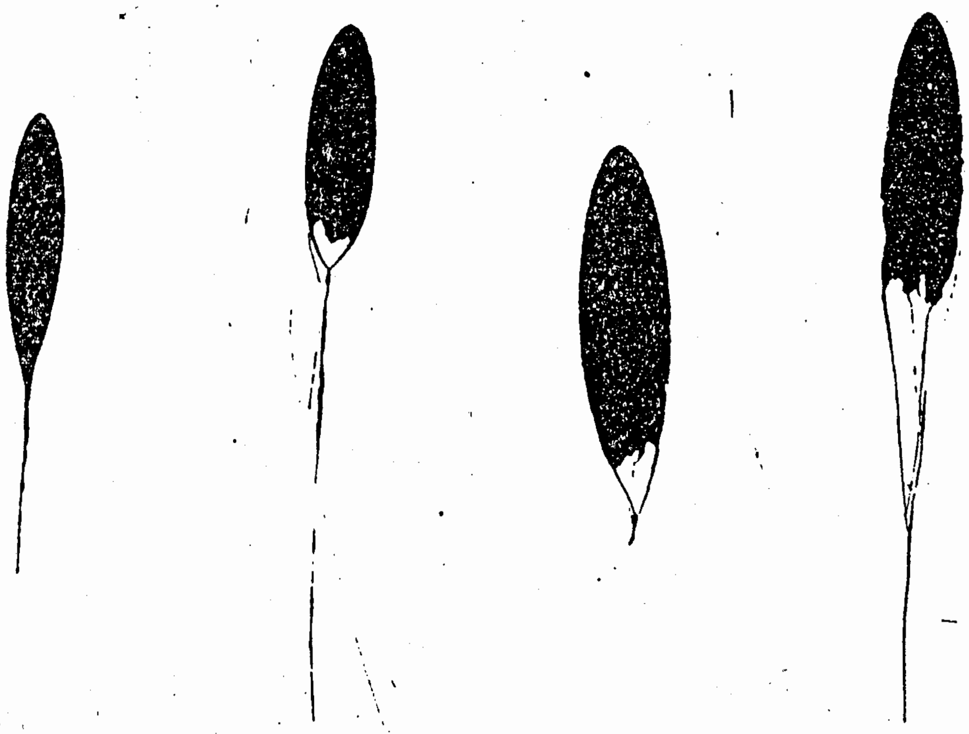


Fig. 12. — Angle d'arrivée : 15°. Hauteur de chute : 1 mètre, 2 mètres, 3 mètres, 5 m. 50 environ. *Grandeur exacte.*

Fig. 12:- Impact angle: 15°
Falling heights: 1, 2, 3, and 5,50 m. appr.
Real size

Fig. 13. — Angle d'arrivée : 5°. Hauteur de chute : 1 mètre, 2 mètres, 3 mètres, 5 m. 50 environ. *Grandeur exacte.*

Fig. 13:- Impact angle: 5°
Falling heights: 1, 2, 3, and 5,50 m. appr.
Real size

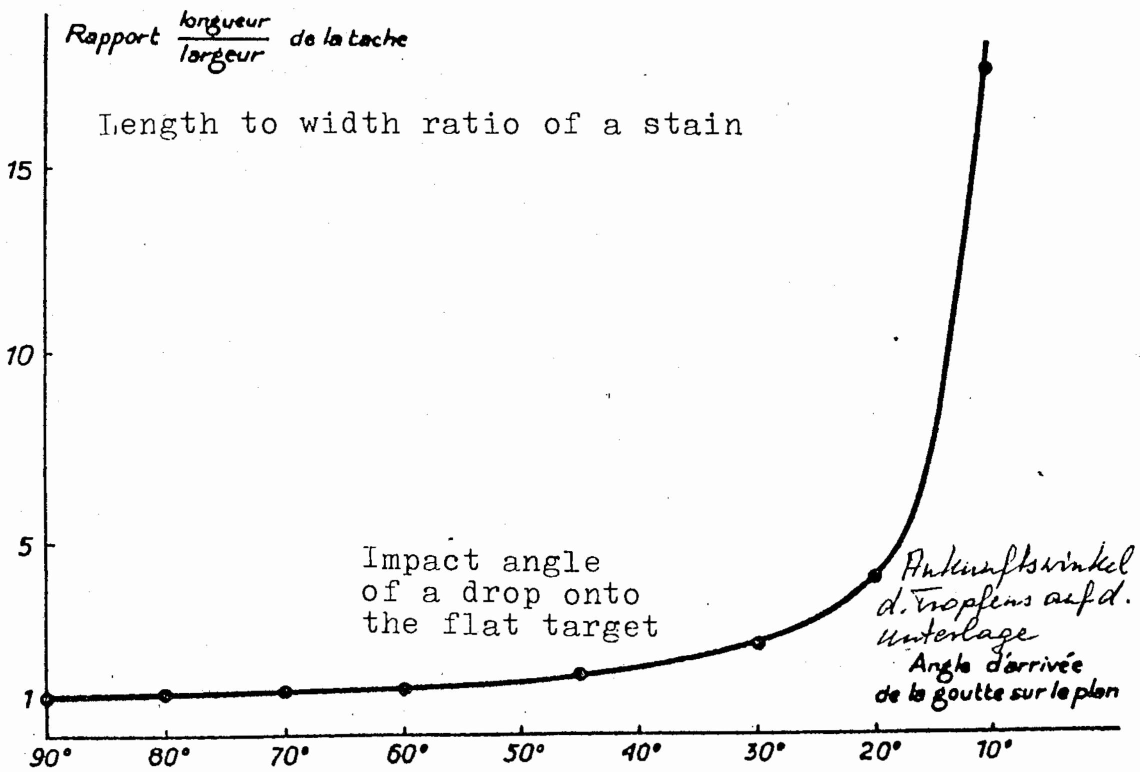


Fig. 14. — Forme de la tache suivant l'angle d'arrivée de la goutte de sang.

Fig. 14:- The shape of a blood staine according to its impact angle.

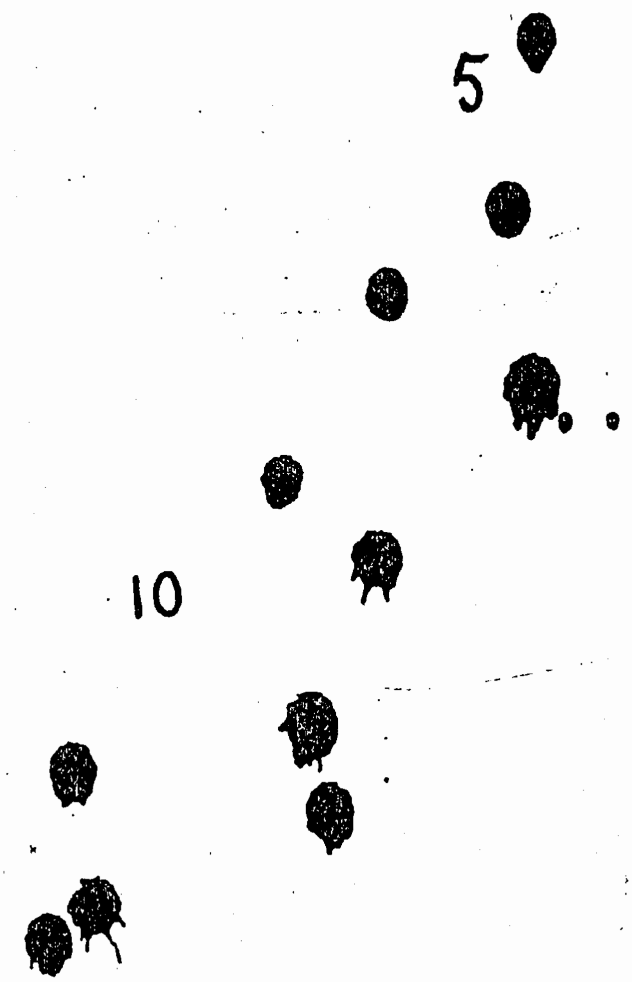


Fig. 15. — A partir d'une certaine hauteur de chute le prolongement inférieur des taches présente plusieurs pointes. Angle d'arrivée : 60°. *Réduction de 1,3.*

Fig. 15:- From a certain falling distance on, there are appearing on the lower end of the stain several spines.
Impact angle: 60° Scale: 1:3

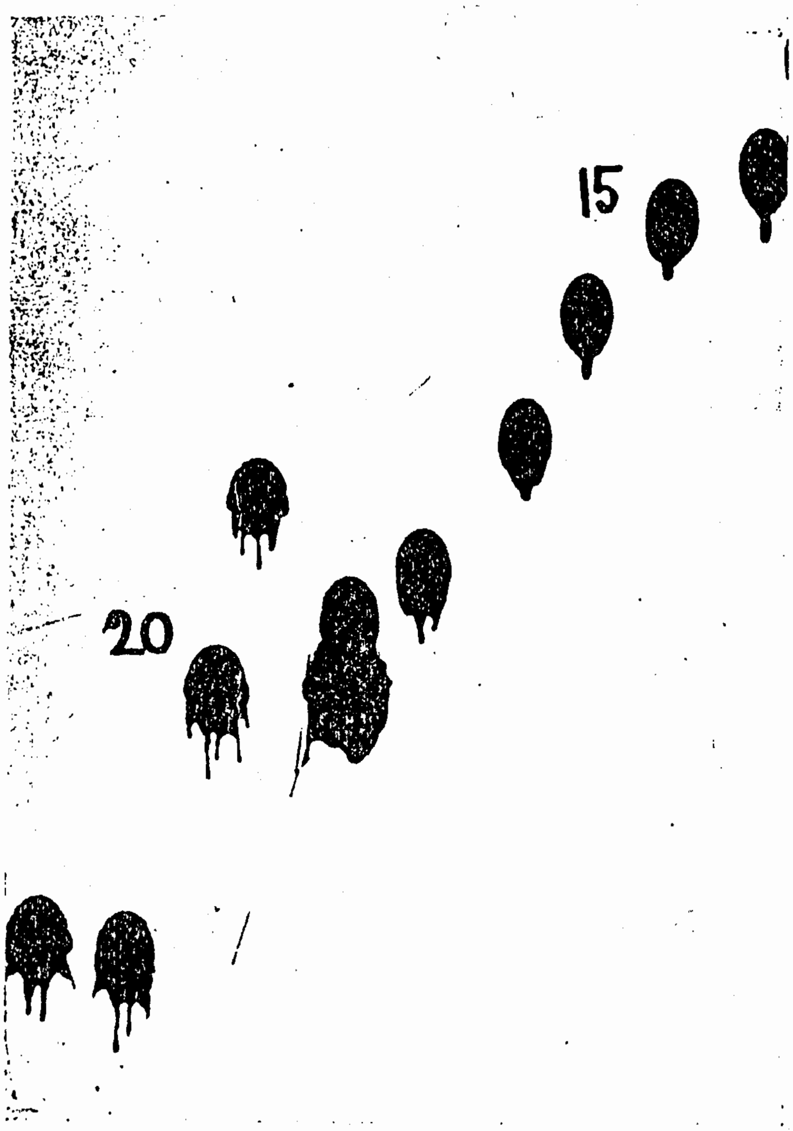


Fig. 16. — A partir d'une certaine hauteur de chute le prolongement inférieur des taches n'est plus unique, en nacelle, mais comporte plusieurs pointes. Angle d'arrivée : 45°. *Réduction de 1/3.*

Fig. 16:- From a certain falling distance on the lower end of a stain is no more nacelle-shaped and not uniformly, but has several streaks.
Impact angle: 45°
Scale diminished: 1:3

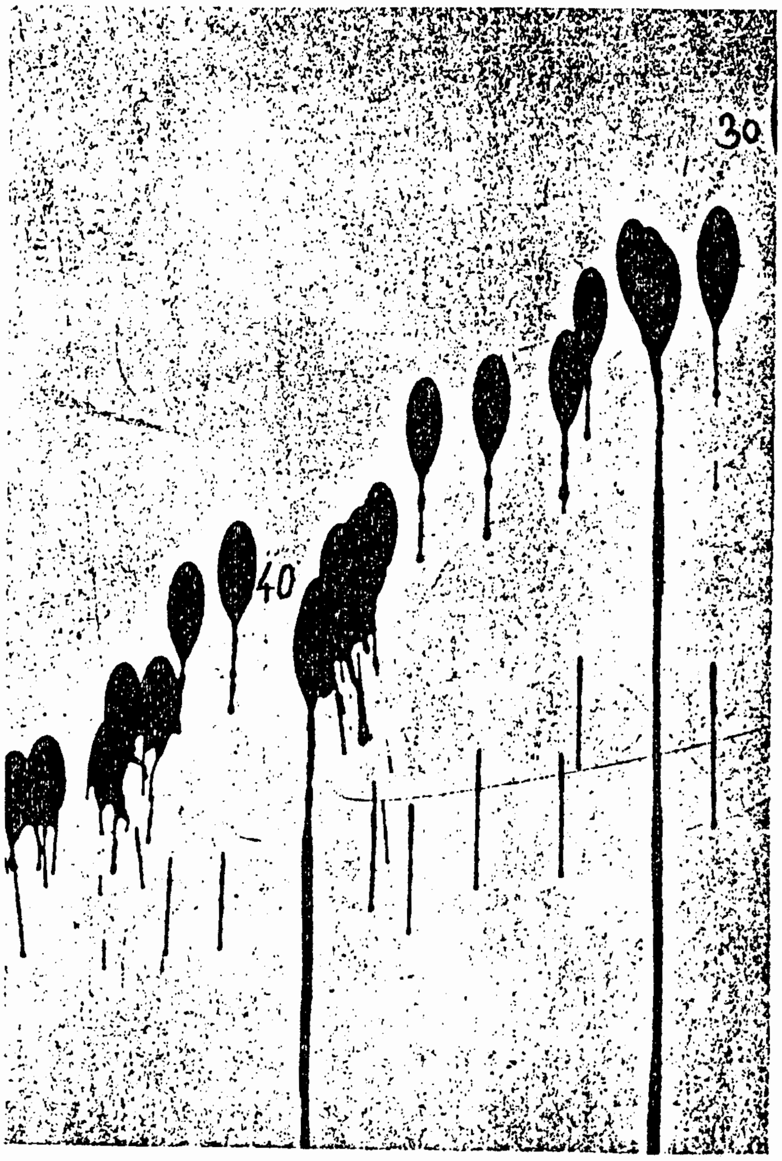


Fig. 17. — A partir d'une certaine hauteur de chute le prolongement inférieur des taches n'est plus unique, en nacelle, mais comporte plusieurs pointes. Angle d'arrivée : 30°. *Réduction de moitié.*

Fig. 17:- From a certain falling distance on the lower end of a stain is no more nacelle-shaped and not uniformly, but has several streaks.
Impact angle: 30° scale diminished: 1:2

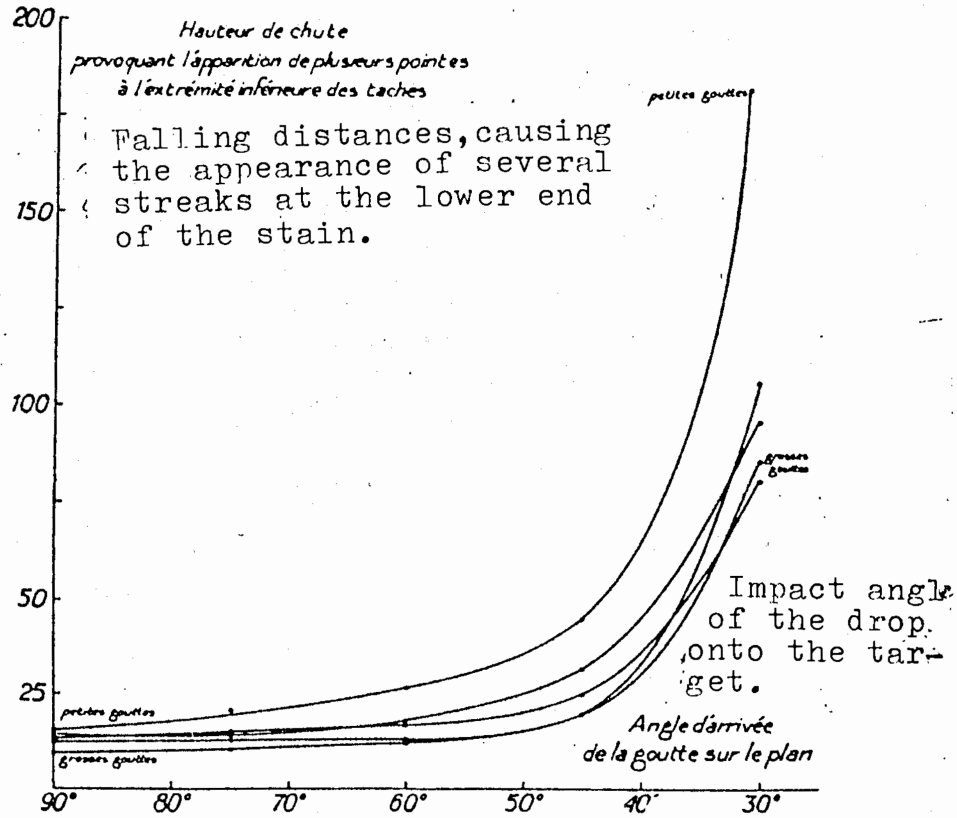


Fig. 18. — La modification de l'extrémité inférieure des taches suivant la hauteur de chute dépend peu du volume des gouttes, pour les angles d'arrivée supérieurs à 50°. (Chaque courbe correspond à une grosseur différente de goutte.)

Fig. 18:- The changes at the lower end of the stains in relation to the falling distance depends very little upon the volume of the drop, when the impact angle is over 50°. (Each curve stand for a different drop size).

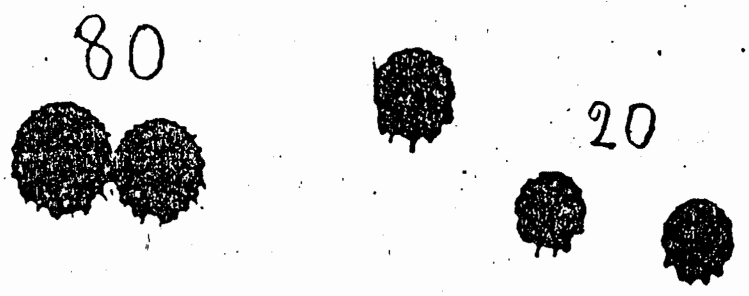


Fig. 19 et 20. — La partie inférieure des taches (zones foncées surmontées d'un liséré clair) est d'autant moins étendue que la goutte de sang tombe de plus haut. Ici : 20 centimètres et 80 centimètres. Angle d'arrivée : 60°. *Grandeur exacte.*

Fig. 19 and 20:- The inferior zone of the stain (the dark zone with the clear strip over it) becomes smaller, as the falling distance rises. Here: 20 and 80 cm falling distances; Impact angle: 60°, Real size.

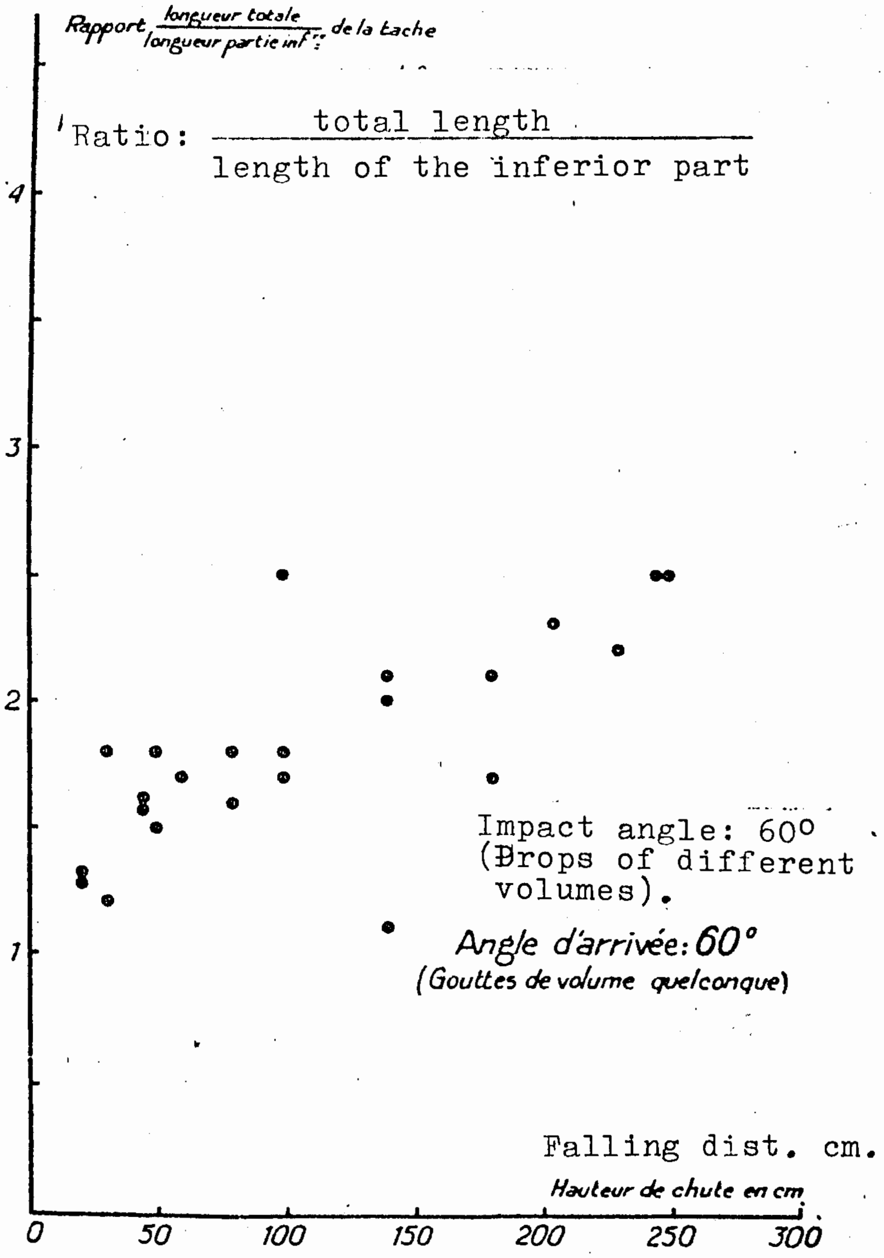


Fig. 21. — Le rapport $\frac{\text{longueur totale}}{\text{longueur partie inférieure}}$ des taches varie avec la hauteur de chute des gouttes de sang qui forment ces taches. Malheureusement cet élément d'appréciation est peu précis lorsque les gouttes sont de volume quelconque.

Fig. 21:- The ratio $\frac{\text{totale length}}{\text{length of the inferior part}}$ of stains

changes according to the change in the falling heights of blood drops which cause these stains. Unfortunately is this feature only little precise when the volumes of the drops are varied and unknown.

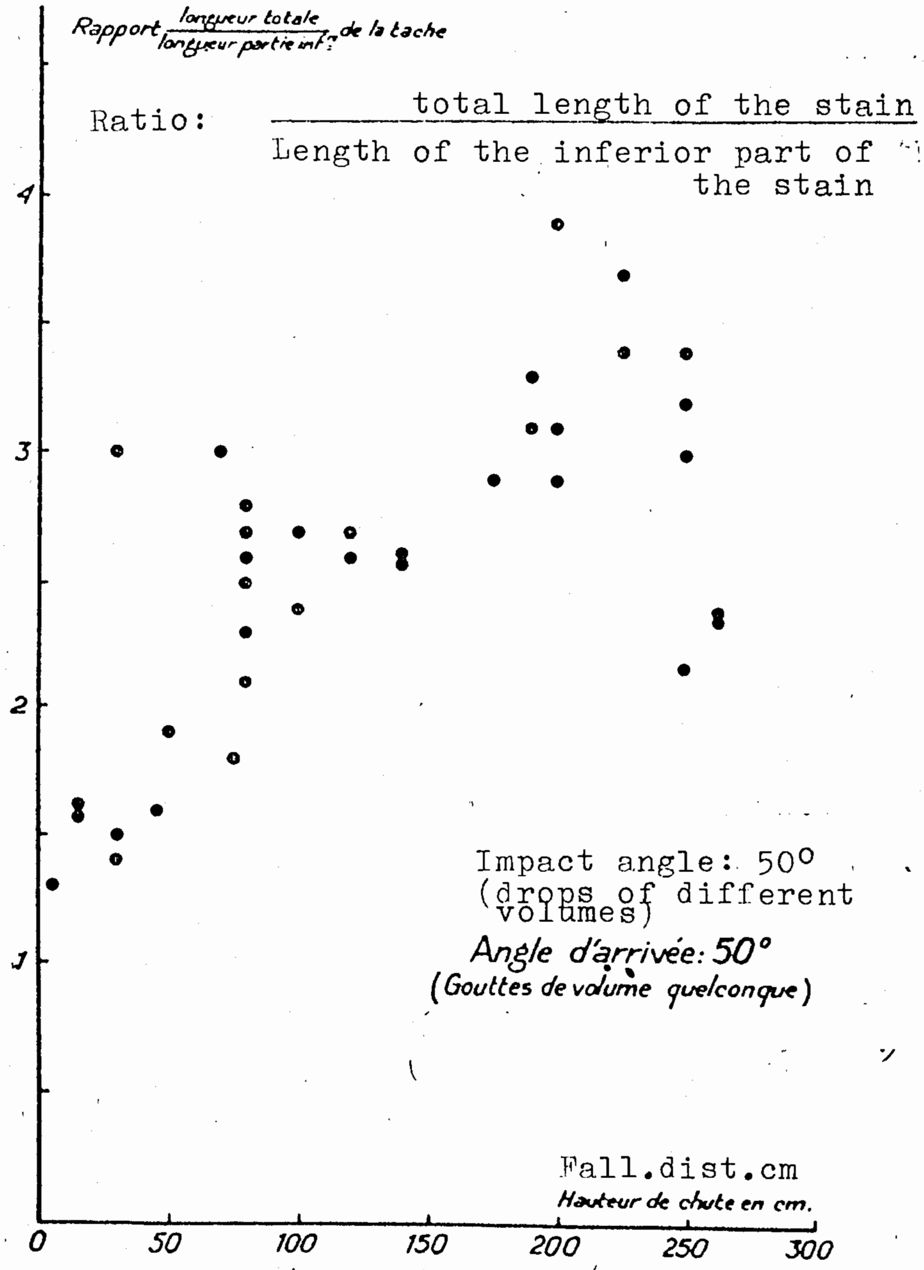


Fig. 22. — Le rapport $\frac{\text{longueur totale}}{\text{longueur partie inférieure}}$ de la tache dépend aussi de l'angle d'arrivée des gouttes de sang. Pour un angle de 50° le rapport est plus élevé que pour un angle de 60° comme le montre la comparaison des figures 22 et 21.

Fig. 22:- The ratio: $\frac{\text{total length}}{\text{length of the inferior part}}$ of a stain depends also upon the impact angle of the blood drop. For an impact angle of 50° the ratio is higher, than for an impact angle of 60° as can be seen when comparing the figures 22 with 21.

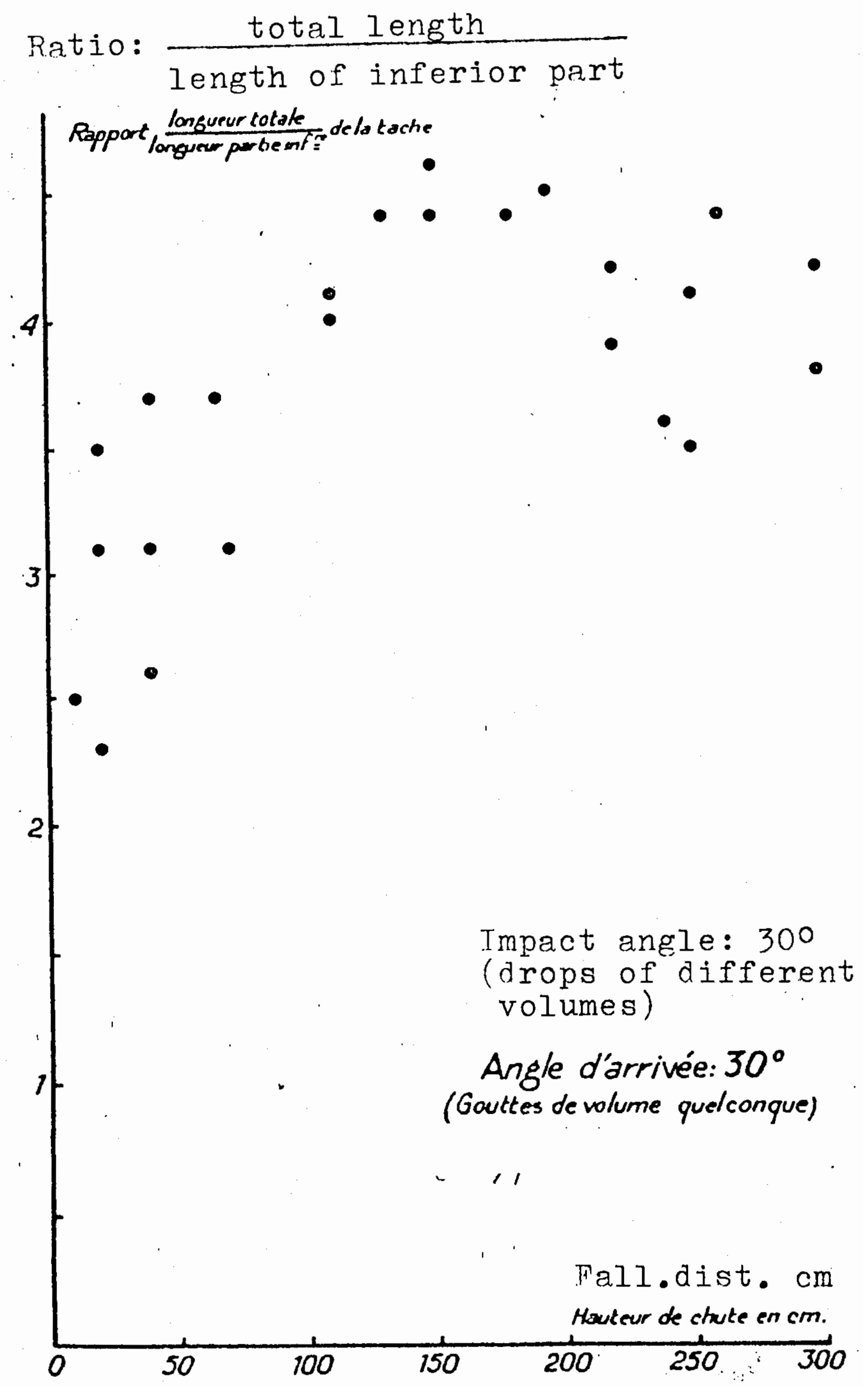


Fig. 23. — Pour un angle d'arrivée de 30° les mesures du rapport $\frac{\text{longueur totale}}{\text{longueur partie inférieure}}$ des taches sont pratiquement inutilisables.

Fig. 23:- For an impact angle of 30 degrees is the ratio $\frac{\text{total length}}{\text{length of the inferior part}}$ of stains practically worthless.

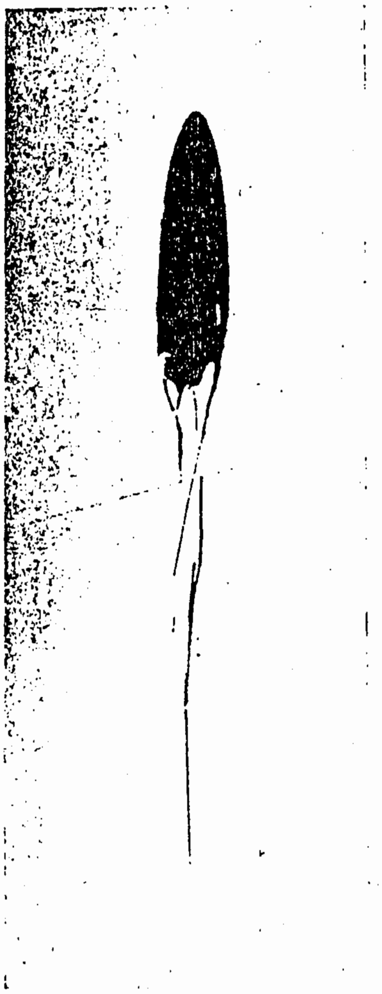


Fig. 24. — Croisement des prolongements inférieurs.
Angle d'arrivée : 15°. ***Grandeur exacte.***

Fig.24:- Crossings of streaks in the lower end of the stain.
Impact angle: 15°
Real size

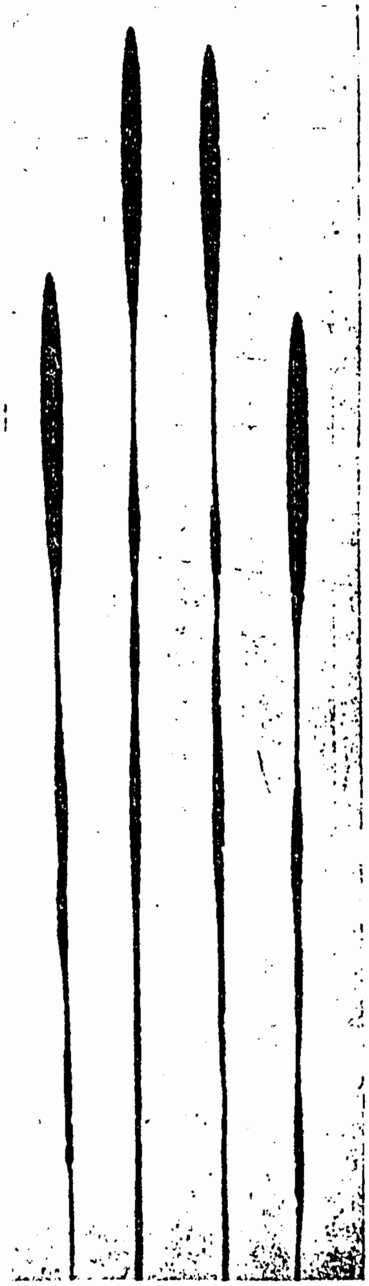


Fig. 25. — Aspects en fuseaux.
Angle d'arrivée : 5°. ***Grandeur exacte.***

Fig.25:- shape of a fuse
Impact angle: 5°
Real size.

Fig. 26. — Aspects en barbes de plume. Angle d'arrivée : 5°. *Grandeur exacte.*

Fig. 26:- Quill-shaped streaks
Impact angle: 5° Real size

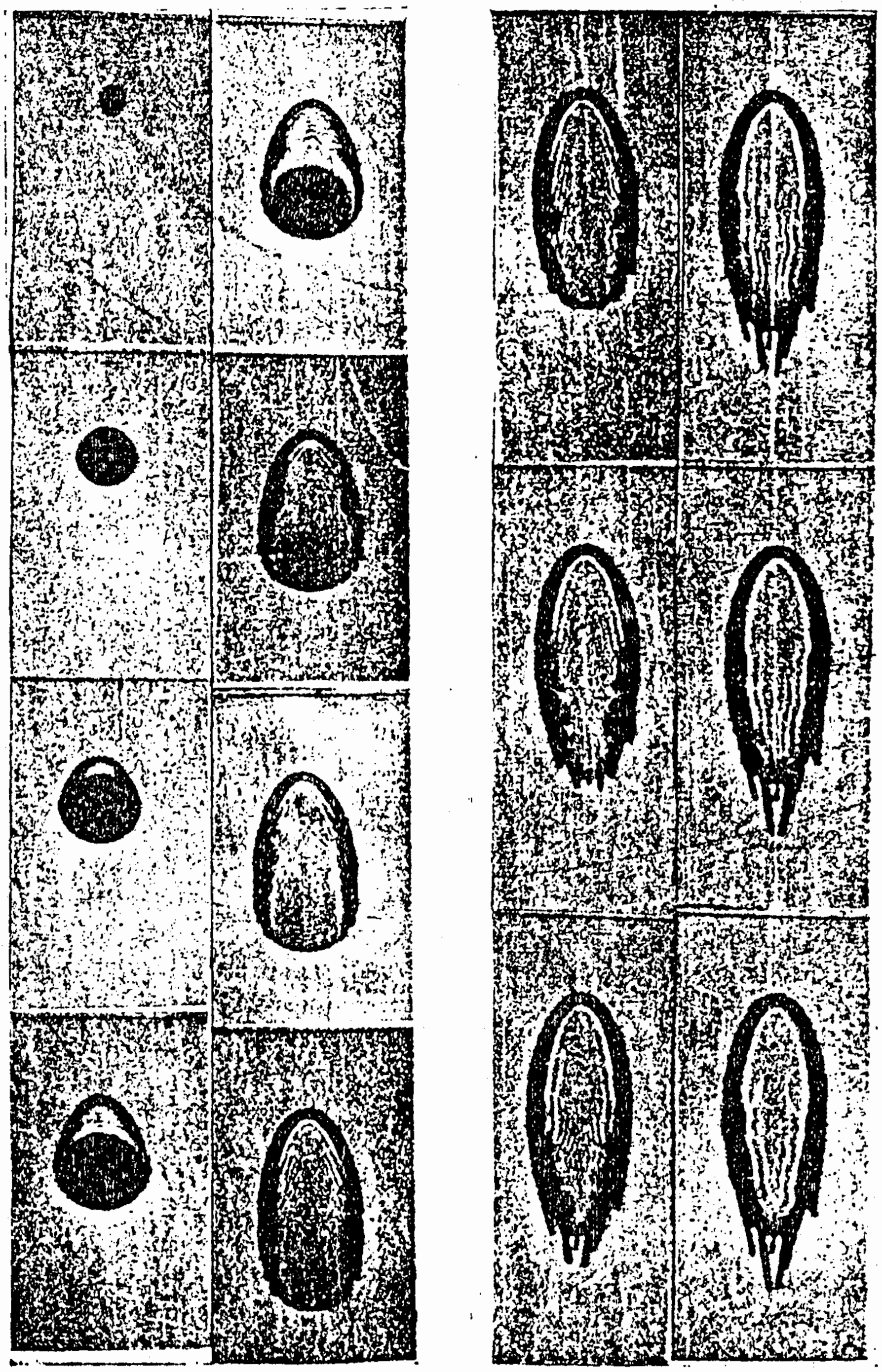


Fig. 27. — Goutte tombant verticalement sur un plan incliné. Hauteur de chute : 80 centimètres. Angle d'arrivée : 20°. 500 PHOTOGRAPHIES PAR SECONDE. *Lire de haut en bas et de gauche à droite.*

Fig. 27:- Drops falling vertically onto an oblique target.

Falling distance: 80 cm

Impact angle: 20°

Speed: 500 fotographs per second

Please regard thr sequence: from top to bottom and from the left to the right.

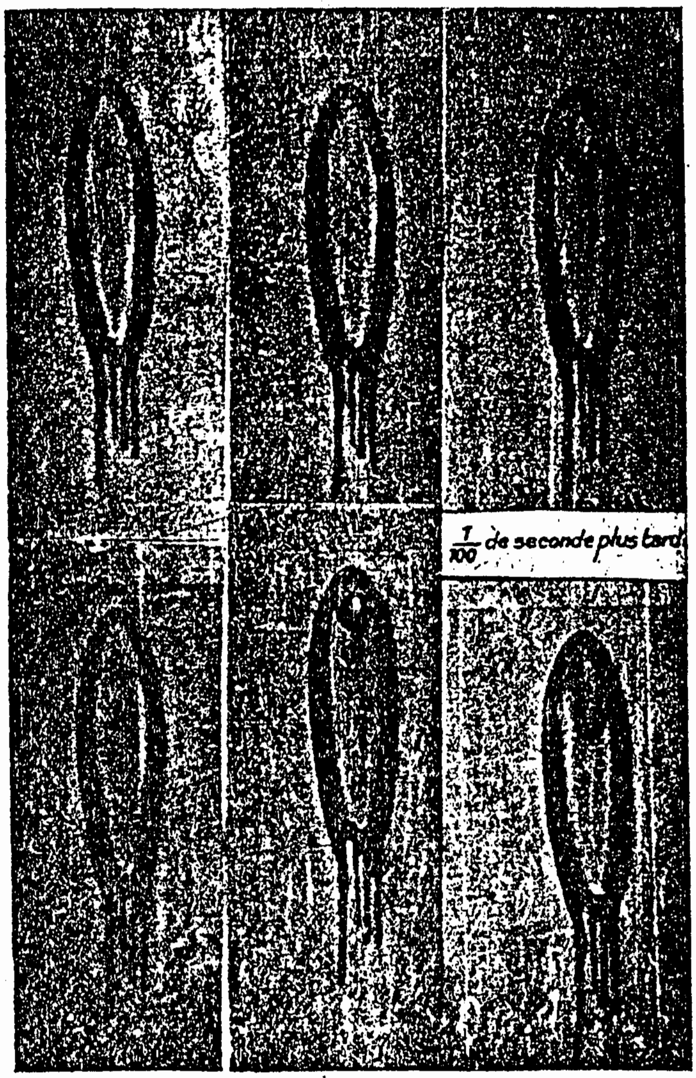


Fig. 28. — Goutte surnuméraire venant donner à la tache son aspect définitif. Hauteur de chute : 80 centimètres. Angle d'arrivée : 20°. 500 PHOTOGRAPHIES PAR SECONDE. *Lire de haut en bas et de gauche à droite.* 4 photographies n'ont pas été reproduites, Il y a donc intervalle de un centième de seconde entre la 5e et la 6e photographie.

Fig. 28:- The additional drop gives the stain its final shape.
Falling distance: 80 cm
Impact angle: 20°
Speed: 500 fotographs per second

Read: from top to bottom and from left to right.

Four fotographs were not reproduced here. This caused the interval of 1/100 of a second between the fifth and the sixth fotgraph.

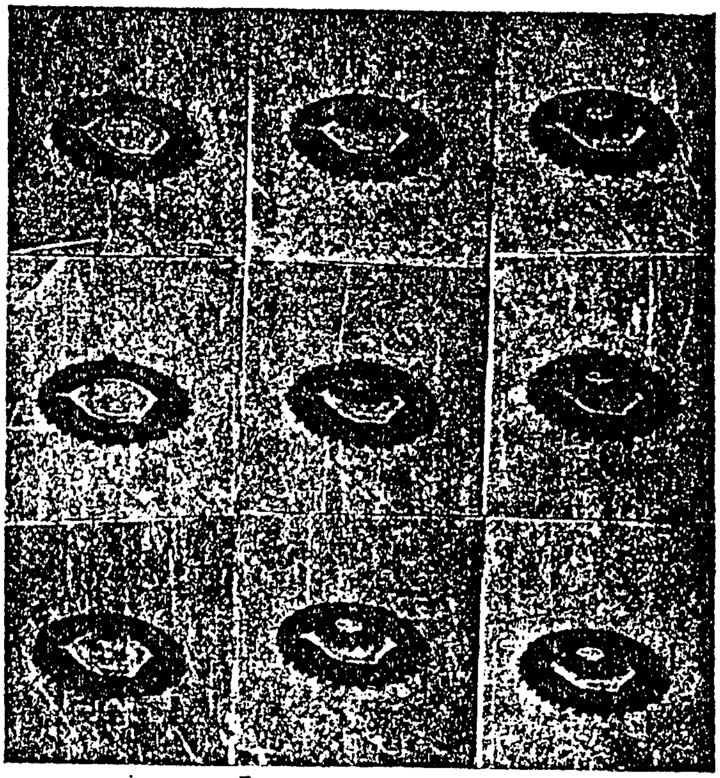


Fig. 29. — Tache produite par une goutte abordant le plan suivant un angle de 60°
(l'inclinaison du plan fait paraître la tache plus élargie qu'elle n'est en réalité).
Goutte surnuméraire venant donner à la tache son aspect définitif.
500 PHOTOGRAPHIES PAR SECONDE. *Lire de haut en bas et de gauche à droite.*

Fig. 29:- A stain caused by a drop falling onto the target under an impact angle of 60°.

The obliquity of the targets surface causes an impression, that the stain is larger, than it is in reality.

The additional drop gave the stain it final shape.

Speed: 500 fotographs per second

Read: from top to bottom and from left to right

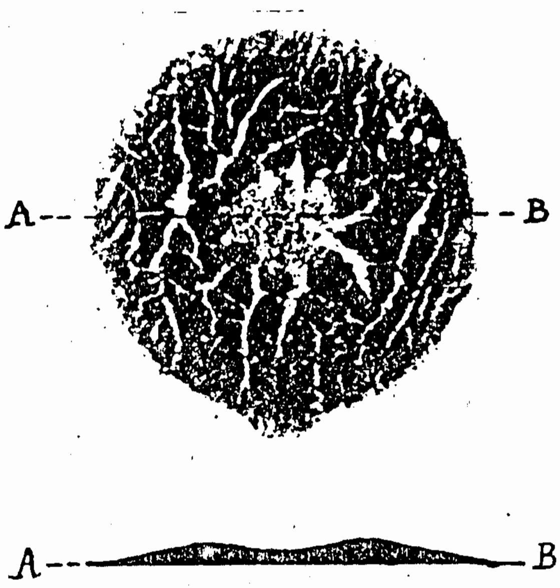


Fig. 30. — Tache de sang peu épaisse avec un centre très mince. *Microphotographie.*

Fig. 30:- Blood stain with a not great volume and with a depressed center. Microfotographie.

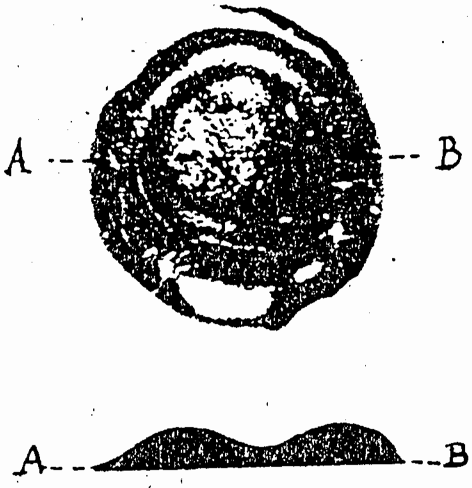


Fig. 31. — Tache de sang plus petite et plus épaisse que la précédente. Centre déprimé. *Microphotographie.* Agrandissement 60 fois. Au-dessous, coupe schématique suivant AB.

Fig. 31:- Blood stain smaller and thicker than the previous one. Center is depressed.
Enlargement: 60 times

at bottom: Same stain in profile.

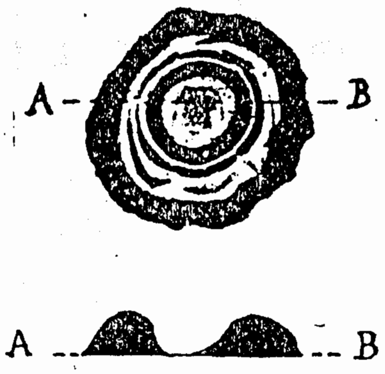


Fig. 32:- The center is completely empty. The blood crust forming the stain has in the center an excavation resambling a well on the ground of which the cardboard can be seen onto which the blood drop fell. On the microfotograph reflexions of the ilumination, forming a crown, can be observed. Enlargement: 40 times.

On bottom: view in profile along the dissecting line A-B.

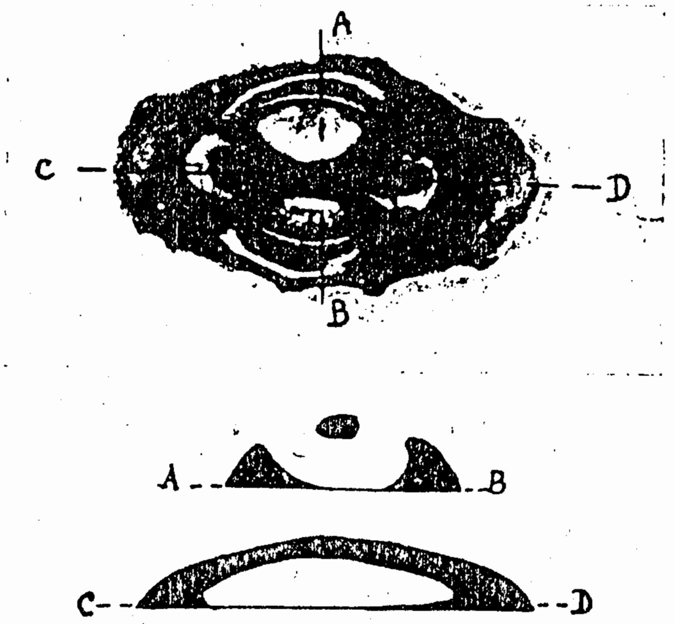


Fig. 33. — Ici existe un pont au-dessus du vide central. *Microphotographie.* Agrandissement 100 fois. Au-dessous, coupes suivant AB et CD.

Fig. 33:- Here is visible a bridge over the void central area. Microfotographie. Enlargement: 100 times. On bottom: view in profile along the dissecting lines A-B and CD.

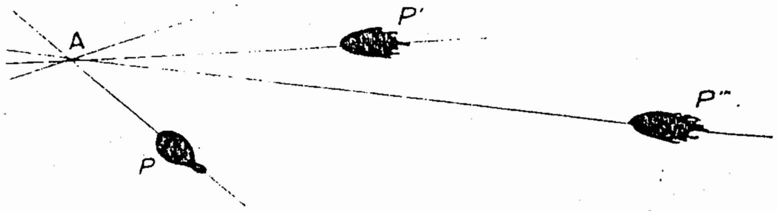


Fig. 34. — La convergence des axes des taches trouvées aux points P, P', P", P‴ détermine le point A.

Fig.34:- The convergence of the axes of the stains found in P, P′ P" P′" determine ejection point "A".

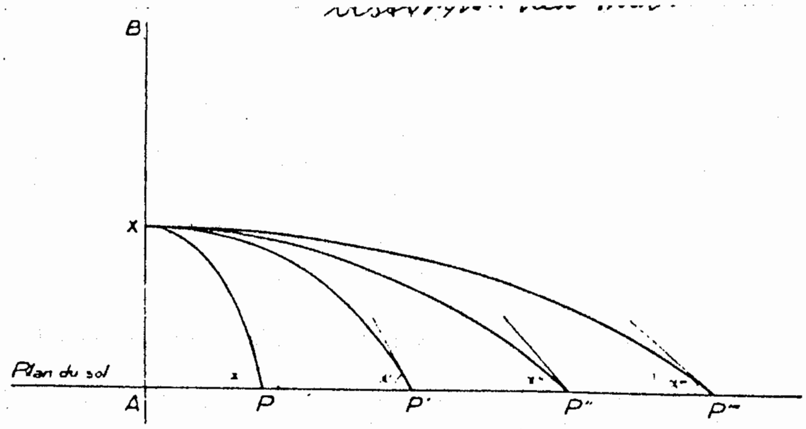


Fig. 35. — Le sang est venu d'un point X situé sur la verticale élevée au point A. La forme des taches aux points P, P', P" permet (voir courbe figure 14) de connaître les angles d'arrivée α, α', α".

Fig.35:- Blood came from point "X", situated on the vertical line above Point "A". The shape of the staines in the positions P, P′ P" permits to find the impact angles a a′ a" (see curves in Fig.14).

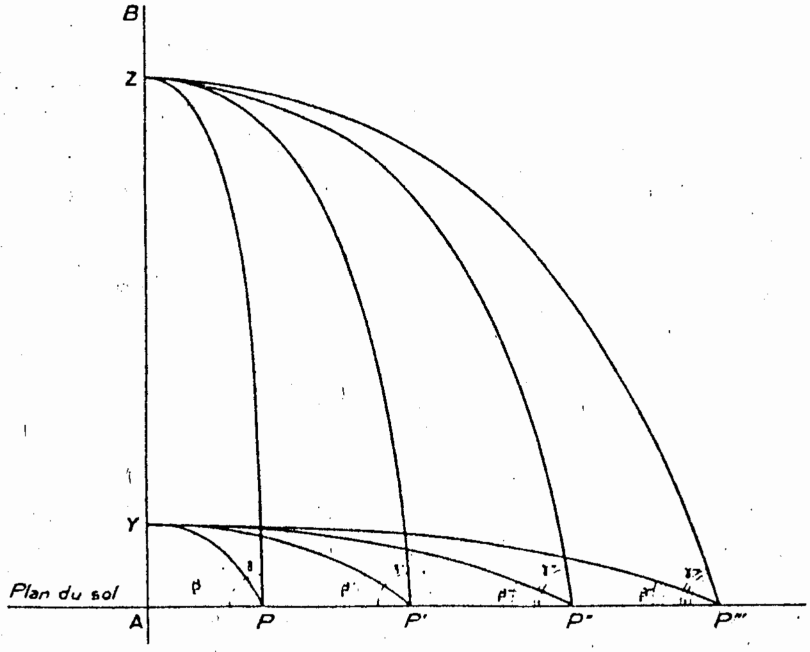


Fig. 36. — Si le sang venait de Y on aurait aux points P, P', P" les angles d'arrivée β, β', β". S'il venait de Z les angles γ, γ', γ".

Fig.36:- If the blood came from "Y" we would have in P, P′ P" the angles b b′ b" . If it came from "Z" the angles would be g g′ g".

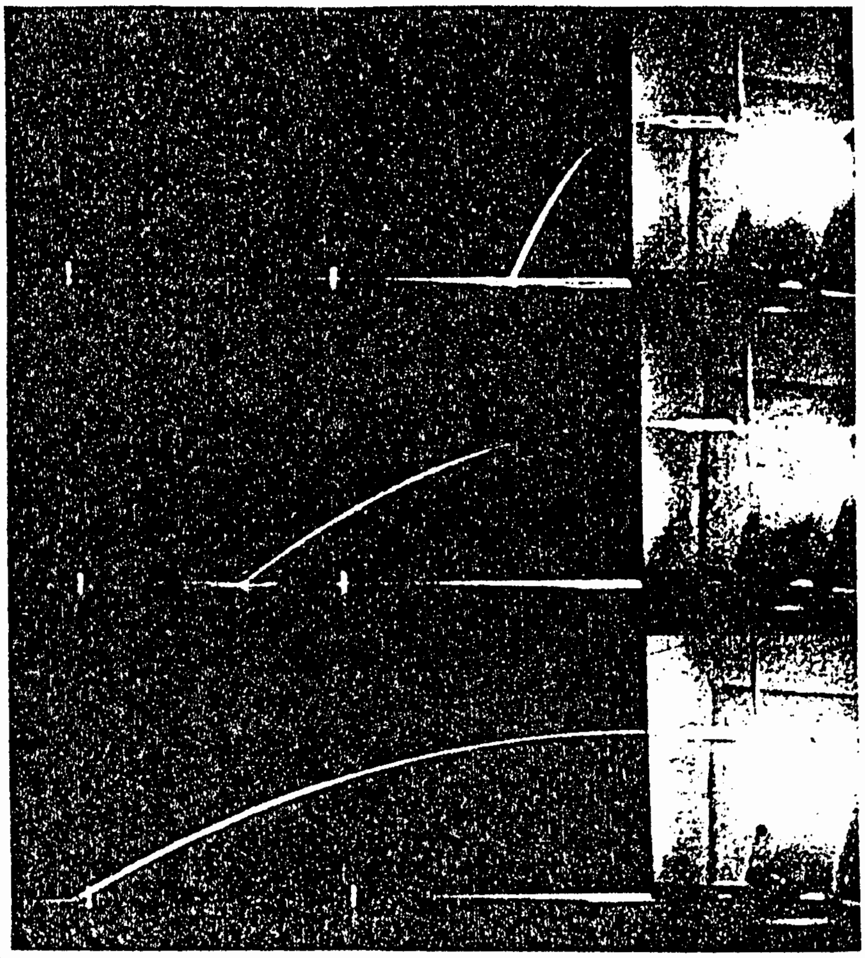


Fig. 37. — Étude d'un ensemble de jets provenant d'un même point situé à 30 centimètres de haut et partis à des vitesses variables d'ailleurs inconnues. L'ensemble des angles d'arrivée en des points définis permet de déterminer la hauteur du point de départ.

Fig. 37:- A study of several jets coming out from the the same point at 30 cm high, at variable, unknown speeds. The assembly of impact angles at the marked points allowed us to determine the hight of the ejection point.

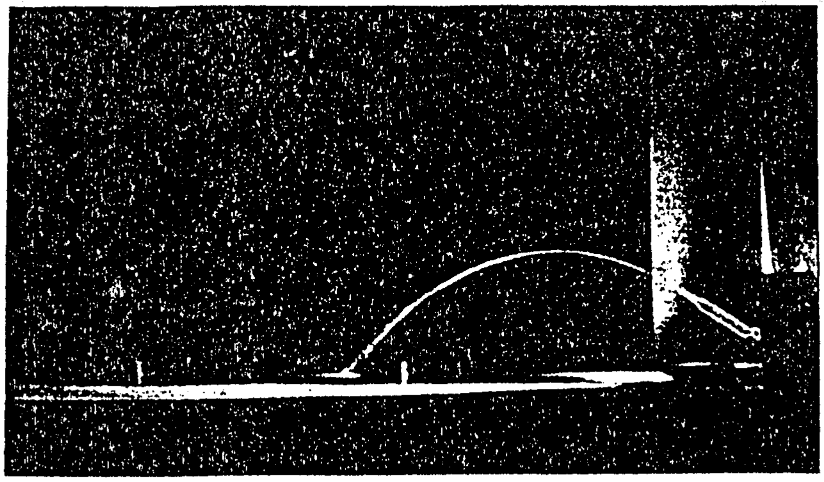


Fig. 38. — En pratique existe une inconnue supplémentaire : on ignore l'angle de départ des jets de sang hors de la plaie. Dans la figure précédente les jets partaient horizontalement. Ici est photographié un jet partant sous un angle de 45°. (Extrémité de la canule à 15 centimètres au-dessus du plan d'arrivée.) Appareil photographique à 3 m. 50 du plan du jet.

Fig. 38:- Practically there exists an additional unknown factor: The angle of ejection of the jet has to be ignored which is the angle under which blood is leaving the open vessel.
In the last figure the jets were horizontally ejected.
Here one is fotographed leaving under a departure angle of 45°, from a point situated 15 cm above the level of the impact site.
The foto was taken from a distance of 3,50 m.

Fig. 39. — Déformation des taches tombées sur un cylindre dont l'axe est incliné à 45°. Cette déformation dépend de la distance du point d'impact à la génératrice la plus élevée du cylindre, surtout, comme l'indique le schéma l'axe de la tache ne coïncide pas avec la génératrice du cylindre.

Fig. 39:- Deformation of stains falling on a cylinder with an 45° inclined axis. The degree of deformation depends upon the distance of the impact point from the cresting line resulting formost in the deviation of the longitudinal axis of the stain, from the direction of the cresting line of the cylinder.

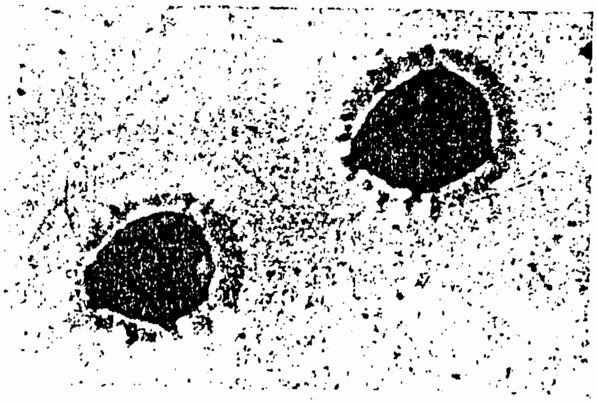


Fig. 40. — Taches de sang sur un carreau de céramique. La goutte s'est étalée en touchant le sol, puis rétractée et a laissé une tache irrégulière. On distingue la zone d'étalement initial.

Fig. 40:- Blood stains on a ceramic tile. The drop has expanded after impact, but then it retracted forming an irregulairly shaped stain. The area of initial expansion can be recognized.

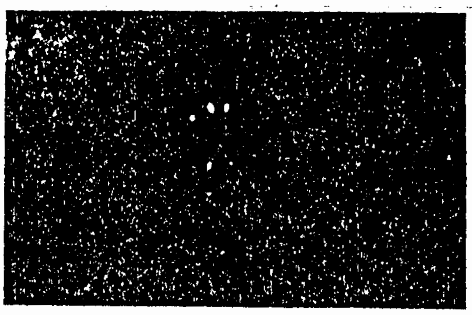


Fig. 41. — Aspect semblable sur une feuille de caoutchouc. En outre, fragmentation de la tache. (Hauteur de chute : 1 m.). *Grossissement* : 1,3.

Fig. 41:- A similiar effect on a piece of rubber. The stain is broken up into fragments.
Falling distance: 1 m; Enlargement: 1,3

Fig. 42. — Rétraction sur une étoffe ayant un apprêt (ici de l'organdi). Angle d'arrivée : 45°. Hauteur de chute : 1 mètre. *Grandeur exacte.*

Fig. 42:- Retractionon an impregnated piece of textile (here mousseline of cotton).
Impact angle: 45°, Falling height: 1 m
Real size.

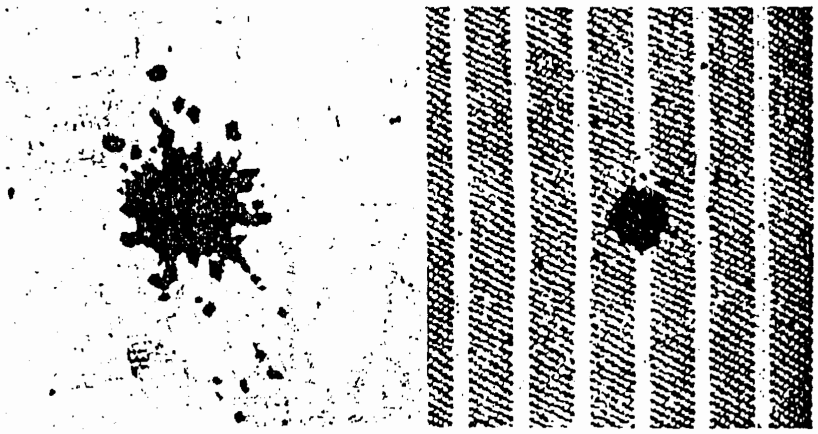


Fig. 43. — Taches produites par deux gouttes de sang de même volume tombées du 1 mètre de haut : à gauche sur du voile de coton, à droite sur de la « finette ». *Grandeur exacte* des taches qui sont fort inégales de dimensions

Fig. 43:- Stains caused by two drops of blood of equal volume, coming from the same falling distance of one meter:
left: onto cotton veil
right: onto feltlike textile
Real size: Please regard the immense inequality in stain size

Fig. 44. — Deux gouttes de sang de volume égal tombées d'une même hauteur de 1 mètre sur un même tissu « peau d'ange » qu'elles ont abordées sous un même angle de 55°. Suivant que la trame du tissu est placé dans un sens ou dans l'autre la tache s'allonge ou s'élargit. *Grandeur exacte.* Fr.Crn

Fig. 44:- Two blood drops of equal volume, falling from the same altitude of 1 meter, arriving under the same impact angle of 55° on the same kind of textile "peau d'ange".
Because of differences in the directionality of the tram, one stain is elongated, the other widened.
Real size

Fig. 45 et 46. — Aspect des taches sur des papiers à surface grenue. Hauteur de chute : 1 mètre. Angle d'arrivée : 45°. *Grandeur exacte.* Les deux gouttes de sang (incoagulable) avaient le même volume.

Fig. 45 and 46
Aspect of stains on paper with granulated surface.
Falling distance: 1 meter; Impact angle: 45o
Real size. Both drops of blood made incoagulable had the same volume.

Fig. 47 et 48. — Aspects arciformes. A gauche sur un papier peint, *grandeur exacte* ; à droite sur une feuille de caoutchouc, *grossissement* : 1.3. Angle d'arrivée : 45°. Hauteur de chute : 1 mètre.

Fig. 47 and 48
archlike forms.
Left: on coloured paper, real size;
Right:on a leaf of rubber, enlargement: 1,3
Impact angle: 45°, Falling height: 1 meter

Fig. 49. — Tache sur un papier peint. Le sang n'a pas adhéré sur un dessin et une partie de la tache est comme amputée. Angle d'arrivée : 45° Hauteur de chute : 1 mètre. *Grandeur exacte.*

Fig. 49:- Stain on colored paper. Blood did not adhere to a painted feature and therefore one side of the stain looks like amputated.
Impact angle: 45°, Falling height: 1 meter,
Real size.

Fig. 50. — Les jours d'une étoffe ont empêché la tache de s'élargir normalement. Angle d'arrivée : 45°. Hauteur de chute : 1 mètre. *Grandeur exacte.*

Fig. 50:- Holes in the textile have impeded the stain to extend normally. Impact angle: 45°,
Falling distance: 1 meter, Real size

Fig. 51. — Tache de sang sur une lame de zinc. Oxydation simulant une rétraction. Angle d'arrivée : 45°. Hauteur de chute : 1 mètre. *Grossissement* : 1,2.

Fig 51:- Blod stain on a sheet of zinc. Oxydation simulates retraction. Impact angle: 45°,
Falling distance: 1 meter; Enlargement: 1,2

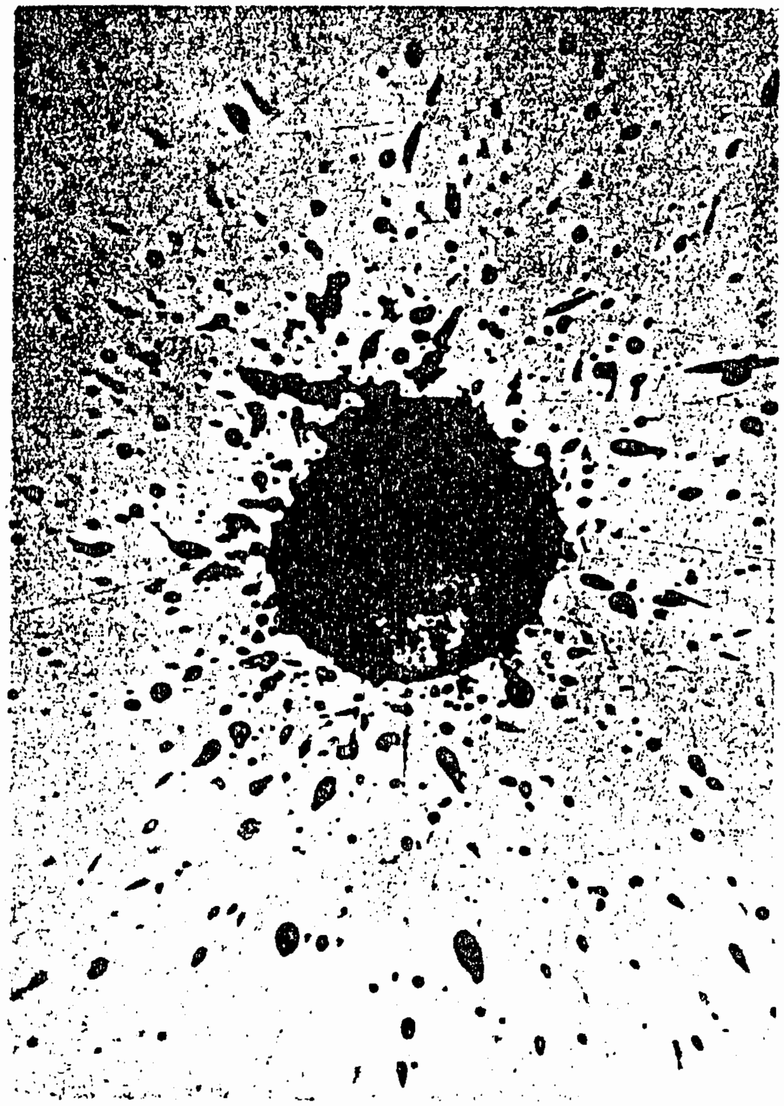


Fig. 52. — Des gouttes de sang tombant sur une flaque de sang ont provoqué d'abord des giclures de sang, noires sur la photographie. Puis le lapin blessé étant mort, le sang s'est coagulé dans la plaie. Il est alors tombé des gouttes de plus en plus claires de sérum qui ont creusé la flaque gélatineuse et provoqué des giclures de sérum, ambrées, claires sur la photographie.

Fig. 52:- Blood drops falling onto a blood pool have initially caused secondary spatter of blood, appearing black on the fotography. Later, when the rabbit died, blood coagulated at its wound. From this time on the drops falling became more and more claire; they were serum drops now piercing the gelatineous blood flake and causing serum spatter of amber color, appearing bright on the fotography.

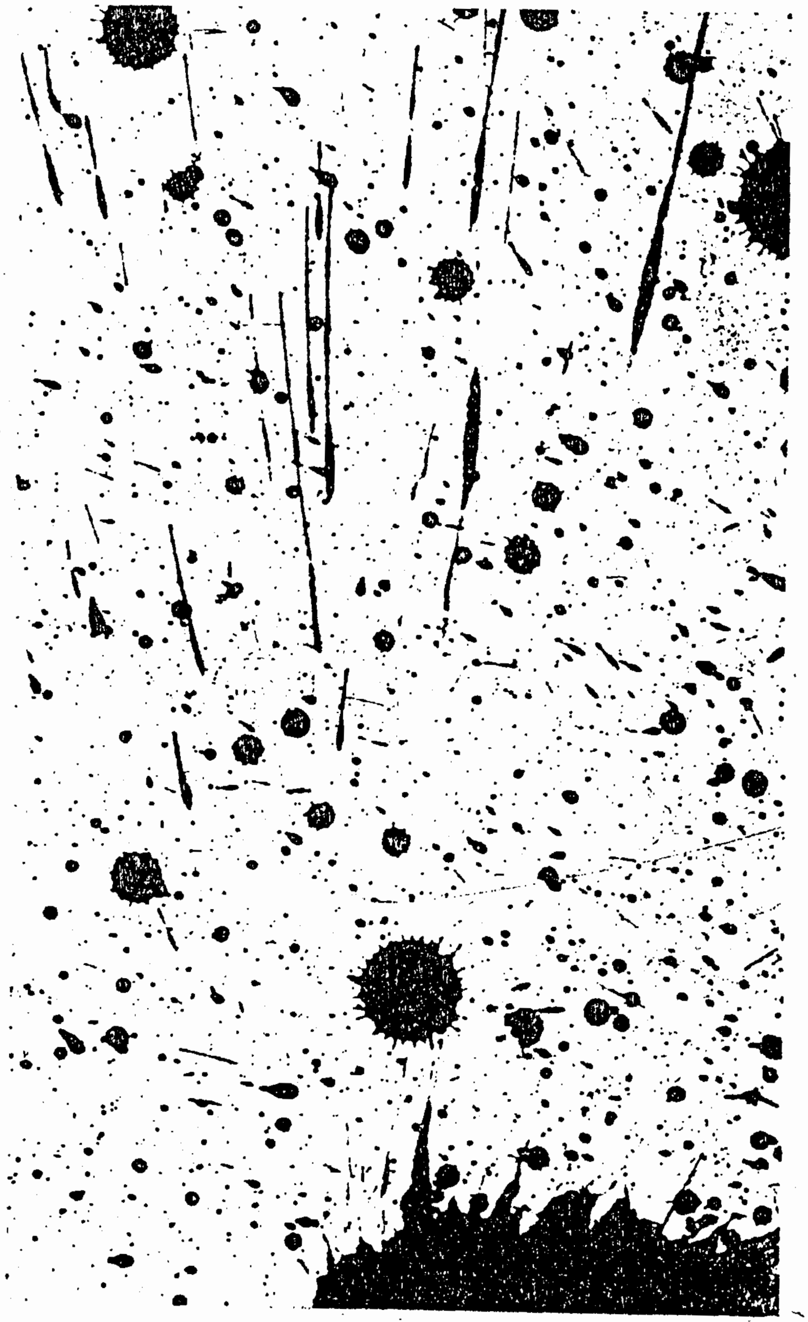


Fig. 53. — Un objet est tombé sur une flaque de sang un certain temps après sa formation et alors qu'elle commençait à coaguler: Il a provoqué la formation des giclures de sérum, ambrées, dont la teinte (claire sur la photographie) tranche sur les taches et giclures de sang (noires sur la photographie). *Grandeur exacte*

Fig. 53:- An object fell into a flake of blood some time after the flake started to coagulate. This caused serum spatter to be spatterd over the blood flake. In the fotography the blood flake appeares dark, really black, and the serum spatter bright (amber). The differences of color are distinct.

Fig. 54. — Brulûres superficielles par des gouttes d'huile bouillante. Formes des taches dépendant de l'obliquité d'arrivée, différente suivant les faces de l'avant-bras, en raison de la forme de ce dernier.

Fig. 54:- Superficial bruises from boiling oil on the skin
The shapes of staines depend upon the degree of
inclination in the arrival point, which were
different on the different parts of the forearm,
because of the nature of the forearm.