# The deposition of fingerprint films

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# The deposition of fingerprint films

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**Abstract.** The contact of human fingers with solid surfaces and their subsequent separation have been studied microscopically. Scanning electron microscopy and contact angle measurements have been applied to examine the deposited film. When a finger touches a surface, a film of liquid present on the finger spreads to produce apparent contact over much of the fingerprint ridge area. Lifting of the finger causes the film to recede and leave a deposit which may be either a distribution of droplets on a thin contaminating layer of adsorbed molecules, or a continuous film: which type is dependent on both the composition of the fingerprint and the nature of the substrate. It is shown that the type of behaviour observed in a particular case is determined by the contact angle between the liquid film and the contaminated substrate surface: in general sebum-rich deposits leave continuous films, whereas eccrine-sweat-rich deposits form droplets.

## 1. Introduction

The importance of fingerprints in the identification of individuals became widely accepted towards the end of the last century following the investigations of Faulds, Galton, Henry and others (see Bridges 1942). Since then, attention in this field has concentrated on the development of latent prints and pattern classification. Of paramount importance in the study of fingerprints are the microscopic characteristics of the process by which they are deposited. Results of an initial survey of this aspect form the basis of this paper.

It is a matter of common experience that a layer of contamination remains on a surface after it has been touched by a finger. The deposit is often immediately visible and clearly shows the papillary ridge pattern, or fingerprint. Even when this is not obvious the deposit may cause significant changes in the physical and chemical nature of the surface, as exemplified by the enhanced adhesion of small solid particles and the decrease in liquid wetting. It is well known in the vapour-deposition of metals that nucleation is inhibited by fingerprint contamination. The print also produces striking changes in the surface potential (Scruton and Blott 1973) and affects the nucleation of salts from solution (Robins *et al* in preparation). Nevertheless the quantity of material involved in a fingerprint deposit is small; usually it weighs no more than 10 μg, ie its mean thickness is of the order of 0·1 μm.

In forensic science chemical and physical methods are used to develop latent finger deposits (Moenssens 1971). However, the physical principles underlying the transfer of material from a finger to a solid surface have only recently become a subject of investigation.

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## 2. Origin and nature of fingerprint material

Before a further discussion of the physical nature of the fingerprint it will be useful to summarize the origin and chemical composition of the material which it comprises (Kuno 1956, Rothman 1954).

The moisture of the finger tips originates primarily from sweat secreted by the eccrine sweat glands. Though present over most parts of the body, these glands are most numerous on the soles of the feet and palms of the hands where their surface density is about 4 per mm$^2$. On the finger tips they occur along the papillary ridges at intervals of about 0·5 mm.

Although eccrine sweat is a dilute aqueous solution the water is rapidly lost by evaporation after secretion. The remaining concentrated solution is a complex mixture of both inorganic and organic components. The composition of this surface film is modified to a variable degree by materials from two other sources: breakdown and flaking (desquamation) of the hardened (cornified) surface layer of the skin on the finger tips, and surface films covering other areas of the body. In particular, sebaceous and to a lesser extent apocrine secretions may be transferred to the finger from the face and hair by occasional contact. An outline of the chemical nature of these materials is included in the appendix but the data are summarized here in the form of a histogram (figure 1); it is apparent that a significant proportion of polar organic material is present on the fingers.

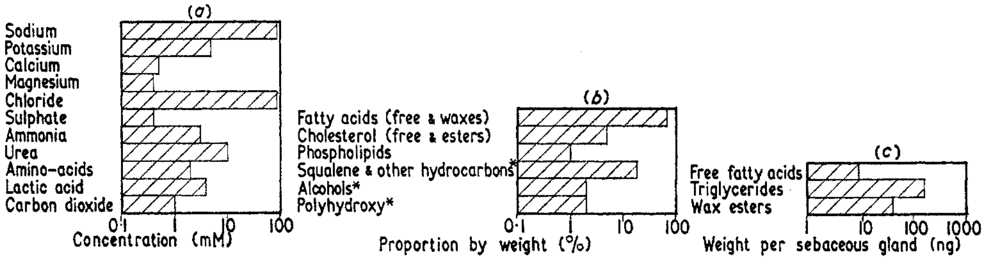

**Figure 1.** (*a*) Histogram showing the concentrations of the major constituents of eccrine sweat. (*b*) Histogram showing the composition of stratum corneum lipids. The concentrations shown apply specifically to stratum corneum except those marked by an asterisk which apply to total epidermal lipid (Reinertson and Wheatley 1959). (*c*) Histogram showing the relative abundance of some components of sebum (values taken from Peter *et al* 1970b).

All constituents are removed by washing, after which the materials from the three sources are restored at different rates. Whereas the sebaceous secretion (sebum) is picked up incidentally the desquamation of the skin is a continuous process but relatively slow compared with the normal rate of eccrine sweating from the fingers. This last is however dependent on the physiological and psychological state of the subject. Only a fraction of the liquid film on the fingers is transferred to a surface by contact; it is possible, under laboratory conditions, to deposit several prints in succession from the same finger without seriously reducing the quantity of material in each.

## 3. Observations and discussion

The composition and abundance of the material covering the fingers have been shown to be variable; nevertheless, a number of general features can be discerned in the behaviour of the material as it is transferred by contact to a solid surface. These are described in the following five sections which deal, in order, with: contact of the finger ridge with a surface; the different form the deposits take; stability of the print material with time; the determination of contact angles as one of the few physical parameters measurable; and the development of a physical model to explain the observed effects.

### 3.1. *Contact area*

The contact of a finger with a solid surface was investigated microscopically. The finger was supported in a narrow channel in a plate, which was pivoted at one end on a knife edge. At the other end a screw provided for adjustment of tilt. A 9 mm hole in the plate allowed part of the finger tip to protrude so that, by adjustment of the screw, contact was made with a plate of transparent material on the upper surface of which a microscope was focused from below.

The finger ridges are rough on a microscopic scale as is evident from the scanning electron micrograph (figure 2, plate) so that true contact with a surface occurs over only a small fraction of the apparent ridge area. However, the film of material normally present on the ridges suffices to fill much of the space between the ridge and substrate, resulting in a large area of apparent contact (figure 3, plate). This area is load-dependent. Under a total load on the finger of 0·5 N a typical ridge had a width 125 μm and apparent contact occurred over 55% of the ridge area; when the load was increased to 10 N the width was 250 μm and the degree of apparent contact 80% (figure 3). Although the quantity of moisture on the finger tips varies considerably on different occasions, under most conditions it is sufficient to give the results described. However, if the finger is artificially dried by being thoroughly washed with acetone a smaller area of apparent contact is observed (figure 4, plate). Contact is made at a limited number of points, and although the width of the contact area is unchanged the degree of coverage is reduced to only 40% or less. The effect of loading the finger is, as before, to increase the width of the apparent contact area by producing new points of contact (figure 4). An important feature is that the areas of the original contact points are largely unchanged. These results indicate that the microscopic ridge surface is not sufficiently deformed by the applied pressure to cause the liquid film to be squeezed out; the principal effect of pressure is to deform the bulk of the ridge so that more points of contact with the substrate are formed.

In the initial observations (figure 3) no difference could be discerned between the points of true contact of the finger with the substrate and the areas of liquid film. This is a consequence of the approximate equality of the refractive indices of the skin surface and the liquid film. The refractive index of skin was estimated by observing microscopically a fine scratch on a glass slide over which had been placed a section of finger ridge of thickness 0·15 mm immersed in glycerol (refractive index 1·47). It was observed that the section of the scratch covered by the skin and that covered only by glycerol were in focus simultaneously, indicating the refractive index of stratum corneum to be 1·47 ± 0·03. The refractive index of the liquid film lies in the range 1·40–1·54 (Thomas and Reynoldson 1975).

### 3.2. *Separation of finger surface from substrate*

The lifting of a finger from a surface causes the meniscus of the sandwiched film to recede leaving along each ridge a deposit which for rapid lifting may take the form of either a continuous liquid pool or a distribution of droplets. Experiments have shown that both the composition of the surface film and the nature of the substrate determine which type of deposit is obtained in a particular case.

Fingerprints containing mostly eccrine sweat were obtained by washing a finger in acetone and then after an interval of several minutes, during which contact of the finger with any surface was avoided, depressing it on to the experimental surface. Prints in which sebum predominated were taken from fingers which had touched the face immediately after being washed in acetone. The sweat-rich prints on all surfaces studied (listed in figure 10) had the form of droplets most of which were between 1 and 30 μm in diameter (figure 5*a*, plate). Sebum-rich prints had a similar form to this on glass, mica, metals and PTFE (figure 5*b*). On the remaining surfaces the sebum-rich deposits consisted of a more or less continuous pool of liquid containing more solid material (figure 6, plate). Prints of uncontrolled composition on this latter group of materials were found to take either of the two possible forms and sometimes both occurred in different areas of the same print.

Slow lifting of the finger from the substrate yielded different results from those for rapid lifting; each type of substrate produced a similar print for both eccrine-sweat and sebum deposits.

Retraction of the liquid film left relatively few droplets, the bulk of the liquid flowing into a small number of islands forming bridges between the finger ridges and substrate. With further lifting of the finger the liquid bridges necked and divided to produce large isolated droplets (figure 7, plate).

### 3.3. *Aging of the deposit*

The appearance of a fingerprint deposit changes slowly. Although some droplets are observed to evaporate to yield salt crystals within minutes of deposition, most of the deposit remains largely unchanged for longer periods. The volume of droplets is known to decrease significantly within 18 h of deposition (Thomas and Reynoldson 1975) as the more volatile components evaporate. At the same time the viscosity increases, a qualitative indication of this change being obtained by drawing a fine stylus over the fingerprint observed microscopically. Droplets in a fresh print are highly mobile, but after several days they become viscous and almost solid, their surface developing a wrinkled appearance (figure 8, plate).

### 3.4. *Contact angles*

Contact angles of fingerprint material freshly deposited on various surfaces were measured within a few minutes using a microscope fitted with a tilting stage, illumination being through the objective. The method is a microscopic development of the system used by Fort and Patterson (1963). The angles of tilt at which selected reflections disappeared provided a measure of the respective contact angles. Disappearance occurred when the extreme edge of the incident light pencil just failed to enter the microscope objective (see figure 9).

For comparison of different surfaces both sweat-rich and sebum-rich prints were taken from the same finger. Contact angles for the various surfaces are shown in figure 10. The most striking feature of the results is that the contact angles for sweat-rich deposits have a higher mean and larger ranges than for the sebum-rich deposits. PTFE exhibits the same range of contact angles for both types of deposit and its relatively high values are

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