Fingermarks, more than just a ridge pattern
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CHAPTER 1

GENERAL INTRODUCTION TO FINGERMARKS AND THEIR CHEMICAL COMPOSITION
1. FINGERMARK IDENTIFICATION

The palmar surface of our hands and fingertips and the plantar surface of our feet and toes are covered with friction ridge on the skin. The friction ridge skin, which helps to grasp objects firmly is composed of unique characteristics, including ridges and pores. As the fingertips of our hands are composed of friction ridge skin, upon contact with a surface, an impression is left behind that has unique details and is called a fingermark [1]. This unique pattern of details can be used during crime scene investigation and aids in the identification or exclusion of possible donors. The skin ridge pattern is formed during fetal development and is exposed to a random formation process [1]. Even identical twins do not possess similar fingermarks, as the friction ridge development is not fully genetically determined. During life, the friction ridge pattern does not change, only in case of severe injury, which can lead to the formation of scar tissue or other formations of the pattern [2]. Because it never has been shown that two individuals share the same fingermarks, it is assumed that every person has unique fingerprints [2-3]. Consequently, fingermarks are an important tool for identification purposes.

![Figure 1. Fingermark features]([4](https://example.com)) Level 1 features

- Arch
- Tented arch
- Left Loop
- Right loop
- Double loop
- Whorl

![Level 2 features](https://example.com)

- Line-unit
- Line-fragment
- Ending
- Bifurcation
- Eye
- Hook

![Level 3 features](https://example.com)

- Pores
- Line-shape
- Incipient ridges
- Creases
- Warts
- Scars

Figure 1. Fingermark features [4]. Level 1, level 2 and level 3 features found in fingermarks

Three types of distinctive features can be recognized in the fingermark identification process. The first type, level one features, is described as the macro detail of the ridges. Different groups can be recognized, including the arches, loops, whorls and a combination of these three groups, as depicted in figure 1 [3-4].
Level two features include characteristic details, called minutiae and entail the specific appearance of the ridges (see figure 1, second row). A line unit or dot is a short fragment between two ridges, whereas a line-fragment is a bit longer than a line-unit. Endings are defined as the place where a ridge ends abruptly. The location where a ridge is split into two ridges is called a bifurcation. An eye or island is formed by two opposing bifurcations [5]. Level two features have sufficient discrimination power and can therefore be used in the identification process. The last characteristics, the level three features, include scars, pores and line shapes (figure 1) [3-4]. Level three features are also described as unique and immutable and can therefore be used in the identification process [4].

Most of the fingermarks found at crime scenes are invisible and need development before the ridge pattern can be visualized. A variety of fingermark development techniques are available, including physical, chemical and luminescent techniques, such as powder dusting, ninhydrin spraying and cyanoacrylate fuming [6]. The best suitable method for the visualization of latent fingermarks is for instance determined by the substrate at which the fingermark is deposited [6]. A developed and recovered fingermark, however does not always lead to the identification of a donor. A limiting factor is the current availability of fingerprints registered in databases. Additionally, fingermarks can be poorly developed, smudged or distorted, which hampers the identification process (figure 2) [7]. Next to the morphologic composition of a fingermark, the chemical composition of a fingermark also holds interesting information about the donor of the fingermark. The chemical composition therefore can be of special interest when fingermarks are useless for the identification process.

Figure 2. Examples of fingermarks useless for the identification process
2. FINGERMARK COMPOSITION

Fingermarks are chemically composed of a combination of endogenous and exogenous material. The endogenous part of the fingermark is mostly determined by sweat secretions and remnant of the human skin. The human skin is composed of two major layers, the epidermis and the dermis, as shown in figure 3. The epidermis acts as a protective barrier between the body and exogenous substances. Five different layers can be recognized in the epidermis, namely, stratum basale, stratum spinosum, stratum granulosum, stratum lucidum and stratum corneum [8-10].

The epidermis is continually regenerated. Skin cells, keratinocytes, originating from the stratum basale migrate through all five different layers, with the stratum corneum as endpoint. During this migration process the keratinocytes change from living cells to dead, hard flattened cells. The process of cell renewing takes approximately 28 days [8, 11]. When the keratinocytes reach the skin surface, cell shedding will occur [8, 11]. During this desquamation process, several proteins and peptides are released to the surface of the skin, which are suggested to be in present fingermarks [12].

The dermis is composed of fibro-elastic connective tissue, which give the skin its strength and flexibility. The major components of this connective tissue are collagen, elastin and the extrafibrillar matrix [8, 13]. Secretory glands can be found in the dermis, including the eccrine, sebaceous, and apocrine glands. Their secretions are released via the ducts, present on the surface of the skin and therefore potentially in fingermarks [8].
2.1 Eccrine glands
Eccrine glands can be found throughout the body, but are most abundant on the soles of the feet and hand palms. Eccrine sweat contains approximately 98% of water, the other 2% is composed of organic and inorganic components [8, 14]. The organic components include constituents like, proteins, peptides, lactate, urea and amino acids of which proteins are the most abundant present in eccrine sweat [15]. In a study performed by Raiszadeh et al proteins and peptides in eccrine sweat were identified and quantified, which led to the conclusion that eccrine sweat is a rich source of important proteins that may reflect the health status of the tissue and individual [15]. Because these proteins were identified in eccrine sweat, it is expected that these proteins can also be found in fingermarks. Keratins, cathepsin-D, albumin and dermcidin are indeed identified in fingermarks [16-18].

Amino acids play a major role in fingermark development techniques, since most of the development techniques target the amino acids. The total amount of amino acids present in fingermarks is estimated to be between 0.3 to 2.5 mg/L. Also, inorganic compounds are secreted via the eccrine glands, such as sodium, potassium, calcium, bicarbonate, chloride and ammonia [8, 12, 14].

2.2 Sebaceous glands
Sebaceous glands, which secretes sebum, are found throughout the body in areas containing hair follicles and are absent on the palms and feet soles [19]. The components present in sebum form a protective coat on the skin and help therefore in heat insulation and protect the body from bacterial infections [19-20]. The facial area, forehead and scalp have the highest density of glands [8]. Although the glands are not present on the fingertips, human behavior involves touching of the facial area and forehead, which lead to the presence of sebum-rich material on the fingertip and thus in the fingermark residue.

The components present in sebum are cholesterol, cholesterol esters, squalene, fatty acids, wax esters, diglycerides and triglycerides [19, 21-22]. In fingermarks, free fatty acids are mostly found, which are formed after breakdown of the triglycerides by bacteria or oxidative processes [8, 19]. Several factors can influence the composition of sebum, including diet, age and gender [8, 12].

2.3 Apocrine glands
The last and least studied glands are the apocrine glands. Apocrine sweat glands are scattered through the body and are mainly located in the armpits, anal regions and pubic zone [8]. Their function is not known, but one of the suggested functions is that the apocrine sweat helps in regulation of the body temperature. Contamination of apocrine sweat with sweat and sebum is almost unavoidable, as they are mixed when they appear on the skin surface, since both gland ducts are present in hair follicles [23]. Therefore, only a few studies investigated the content of apocrine sweat. Apocrine sweat is
described as a milky protein-rich fluid and contains besides proteins also ammonia and lipids [8, 23-25].

2.4 DNA
Deoxyribonucleic (DNA) can also be found in fingermarks. DNA analysis is seldom performed on fingermark traces, because in most cases the amount of DNA present in fingermarks is too low to obtain a full DNA-profile. The amount of DNA found in fingermarks is varying from no detectable amount of DNA to hundreds of picograms [26-27]. DNA can originate from epithelial cells, saliva and other body fluids. Differences can be found in the DNA shedder status of individuals. Some individuals are able to leave DNA, directly after hand washing and minimal contact time, whereas others hardly leave any DNA after contact [28]. Moreover, DNA analysis is destructive for the fingermark pattern.

2.5 Exogenous components
Next to the endogenous components, also material originating from exogenous sources can be present in the fingermark deposition. The fingermark secretions can be contaminated with food residues, bacteria, cosmetics, dust, but also drugs and explosives [8, 29-30].

3. OUTLINE OF THIS THESIS
Currently, only the fingermark pattern is used for identification purposes. However, in most cases no donor can be assigned to fingermarks, resulting in unusable fingermarks for the crime scene investigation. As described in the above paragraphs, fingermarks are more than just a ridge pattern and potentially holds a wealth of information that is not included in forensic investigation yet. Proteins, amino acids and fatty acids can provide additional information about the donor of the fingermark, but can probably also be used to obtain additional knowledge about the fingermark itself, like the age since deposition.

Therefore, the aim of this thesis is to develop techniques that aid in the detection, analysis and identification of components present in fingermarks using immunolabeling and fluorescence spectroscopy.

We hypothesized that an important technique that is able to obtain additional donor profiling information from fingermarks will be immunolabeling. The basics of this immunolabeling method will be discussed in the first part of chapter 2. To use immunolabeling in the forensic field the possibilities and limitations of this technique need to be addressed. In chapter 3, the detection of multiple components in a single fingermarks using immunolabeling is described. Another important condition to make this immunolabeling method applicable to the forensic field, is the compatibility of the immunolabeling technique with fingerprint visualization techniques. Most of the fingermarks found at crime scenes are invisible and need development. Chapter 4 and
study the applicability of different fingerprint visualization techniques with the immunolabeling method. Additionally, the applicability of the immunolabeling method with forensic relevant surfaces is described in chapter 6.

One important feature of the chemical components present in fingermarks is their ability to display an autofluorescent signal when excited with the proper wavelength. In the second part of chapter 2, detection of the autofluorescence of is described. The components that are responsible for this autofluorescence are hardly known. Chapter 7 studies the autofluorescence of fresh fingermarks and gives an indication about which components are likely to contribute to the autofluorescence signal. In chapter 8, the relation between the autofluorescent signal and amount of DNA present in fresh fingermarks is studied. We noted that the autofluorescence changes in aged fingermarks. Therefore, in chapter 9 the autofluorescence of aged fingermarks and the components contributing to the change in autofluorescence is investigated. Additionally, a new method is introduced in chapter 10, that is able to estimate the age since deposition of fingermarks using the autofluorescent properties of fingermarks.

In chapter 11, a short review is given, in which different methods are compared that can be used for donor profiling of fingermarks, concluding with a general discussion and final remarks in chapter 12.

REFERENCES