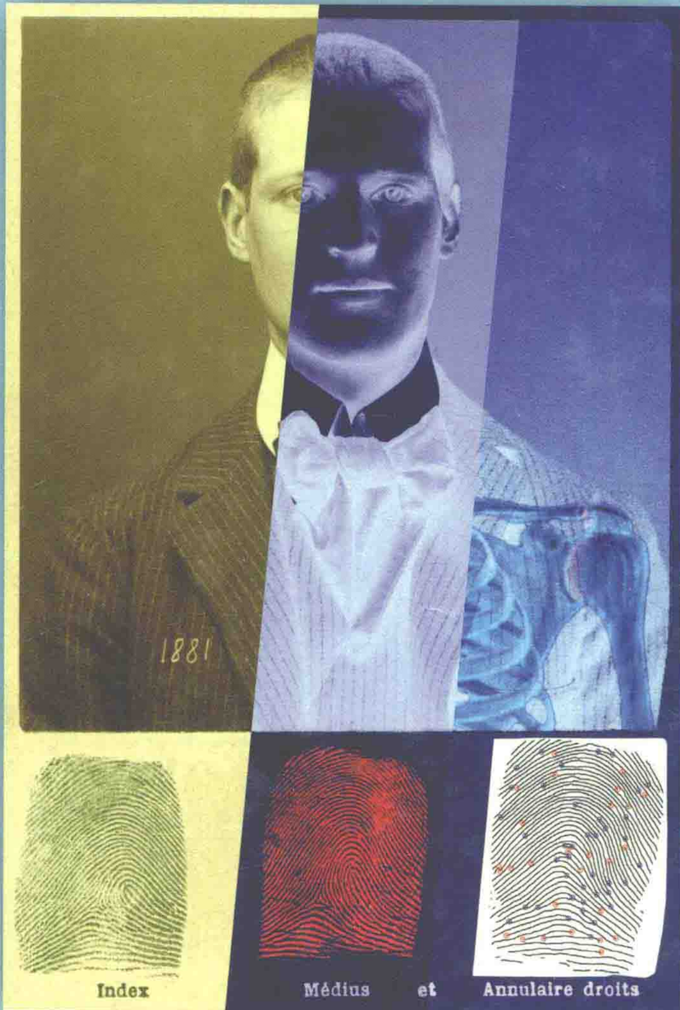
INTERNATIONAL FORENSIC SCIENCE AND INVESTIGATION SERIES

Fingerprints and Other Ridge Skin Impressions



Second Edition

CHRISTOPHE CHAMPOD
CHRIS LENNARD PIERRE MARGOT
MILUTIN STOILOVIC

CRC Press
Taylor & Francis Group

Second Edition

Fingerprints and Other Ridge Skin Impressions

CHRISTOPHE CHAMPOD
University of Lausanne
Switzerland

CHRIS LENNARD
Western Sydney University
Australia

PIERRE MARGOT
University of Lausanne
Switzerland

MILUTIN STOILOVIC
Optimum Technology
Australia

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Printed and bound in India by Replika Press Pvt. Ltd.

Printed on acid-free paper
Version Date: 20160120

International Standard Book Number-13: 978-1-4987-2893-5 (Hardback)

Library of Congress Cataloging-in-Publication Data

Names: Champod, Christophe, author.
Title: Fingerprints and other ridge skin impressions / Christophe Champod, Chris Lennard, Pierre Margot, Milutin Stoilovic.
Description: Second edition. | Boca Raton, FL : CRC Press, 2016. | Series: International forensic science & investigation series ; 27
Identifiers: LCCN 2015044800 | ISBN 9781498728935 (alk. paper)
Subjects: LCSH: Fingerprints. | Fingerprints--Identification. | Criminal investigation. | Forensic sciences.
Classification: LCC HV6074 .F564 2016 | DDC 363.25/8--dc22
LC record available at http://lccn.loc.gov/2015044800

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

Preface to the Second Edition

We initially thought that a new edition was a simple matter of updating the previous edition; however, we soon had to admit that far-reaching changes for the professions—both in the detection and identification processes—needed a thorough treatment. The general outline and subdivision found in the first edition is retained, and, as with the first edition, our focus is on fundamental issues (whether in the identification process, the detection processes, the semantics, or ongoing research). Indeed, valuable books and chapters go into the details of current detection procedures, whereas we have kept an outline of what would be widely applicable methods that would help detect a large majority of ridge impressions, while keeping paragraphs dedicated to future and potential developments. Over the 13 years since the first edition, the scientific literature in this area has exploded (over 1,000 publications) and the related professions have been shaken by errors, challenges by courts and other scientists, and changes of a fundamental nature related to previous claims of infallibility and absolute individualization. This implies fundamental changes in the way training, identifying, and reporting should be conducted. We address these questions with a definite view of where the profession has to go and what efforts and research should help develop the field over the next few years. We propose solutions that were already watermarked in the previous edition but with a full development of probabilistic and decision theories that will support the identification process. The mask is down, and this should lead to heated debates in the near future as many practitioners have not yet realized the earth-shattering nature of the changes. This is a book, we hope, that will prepare the reader for the challenges ahead.

We are also pleased to announce that we have a website for the book where you can access additional resources such as Bayesian networks, comparison tools, and updated reagent formulations. The website address is http://esc-app.unil.ch/blogs/forsi/.

Such a venture would not have been possible without the contributions of many colleagues and researchers from the University of Lausanne whom we acknowledge. They are Alexandre Anthonioz, Andy Bécue, Alex Biedermann, Marco de Donno, Nicole Egli Anthonioz, Aline Girod, Tacha Hicks Champod, Sébastien Moret, Eric Sapin, Franco Taroni, Romain Voisard, and Céline Weyermann. Also, there have been numerous other colleagues from around the world who have had a strong influence on our work over the past years and have helped us shape our thinking on relevant issues. Conscious that it is hard to be exhaustive, we thank Yossi Almog, JoAnn Buscaglia, Toni Cantu, Itiel Dror, Heidi Eldridge, Ian Evett, Jean-Christophe Fondeur, Austin Hicklin, Anil Jain, Terry Kent, Glenn Langenburg, Didier Meuwly, Cédric Neumann, Michio Okajima, Robert Ramotowski, James Robertson, Claude Roux, Xanthe Spindler, David Stoney, the members of the Scientific Working Group on Friction Analysis, Study and Technology, and the members of the International Fingerprint Research Group.

Finally, we dedicate this book to our families for their unquestioning love and support.

Lausanne, Canberra, and Sydney

Preface to the First Edition

Our aim with this book was to place, under the same roof, two distinct but intertwined aspects of the use of fingerprinting for personal identification and criminal investigation: (1) the aspects associated with the visualization, detection, and recording of friction ridge skin impressions and (2) the issues regarding the identification or individualization of unknown marks when compared with known prints. In 1978, Robert Olsen (1978) published one of the rare books where both aspects were covered with equal weight. Two of us published an overview of fingerprint detection techniques, putting significant emphasis on detection sequences (Margot and Lennard 1994); however, the identification process was only briefly covered. In recent years, we have all been involved in various research projects on fingerprint detection techniques as well as identification issues. We have tried to reflect these dual aspects through our mandate to regularly update the forensic community on the field for the triennial Interpol Forensic Science Symposiums in Lyon (Margot and Lennard 1993; Champod and Margot 1997, 1998; Meuwly and Margot 2001). We have observed a field that is in rapid progress on both detection and identification issues, and in light of the recent debate on the admissibility of fingerprint evidence in US courts, we have decided to bring together both sides of this discipline within the same volume and to give them the evenhanded critical analysis they deserve. Our chapters are arranged as follows:

In Chapter 1, we give a brief overview of the current state of knowledge on the morphogenesis of friction ridge skin. Our objective is to embed the identification process on a firm ground of understanding of biological uniqueness. We are particularly grateful here to Prof. Michio Okajima, who has shared with one of us his time, extensive knowledge, and photographic material during a wonderful summer afternoon in Tokyo in 1996.

In Chapter 2, we investigate the nature of the identification process. We have tried to step beyond the well-known ACE-V protocol, which does not completely fulfill the requirements—as described by van Koppen and Crombag (2000)—of (1) a fully articulated descriptive model, (2) a detailed and systematic account of the variation of the features, and (3) a transparent decision model. Consequently, we put some effort into making explicit the available knowledge, with special emphasis on the documented selectivity of fingerprint features. We have also made a deliberate attempt to reconcile the two main approaches to the identification process: an approach based on an empirical numerical standard (a predefined number of points) and a holistic approach. We believe that most of the antagonism of this debate fades away when an appropriate perspective is adopted on the concept of identification standards: a sound professional framework founded on a sound corpus of scientific data, high standards of quality management, proficiency testing, performance monitoring, and blind testing.

Chapter 3 presents the knowledge of chemistry, optics, and photography that is necessary to develop skills and understanding in detection techniques. We felt that it was important to draw special attention to the use of filters, optical enhancement techniques, and also digital image processing. Following the creation of the School of Forensic Science (Institut de Police Scientifique) at the University of Lausanne in 1909, Prof. R. A. Reiss taught pioneer forensic scientists to maximize and secure the recovery of evidential marks through the expert use of photographic techniques (Reiss 1903). The importance of the recording process can never be overstressed.

In Chapter 4, the major fingerprint detection techniques are reviewed according to the type of surface encountered. The chapter starts with information regarding the composition of fingermark residue, allowing an understanding of the nature of the components targeted by the detection techniques and the added value of detection sequences as opposed to a single treatment. It is not intended to provide an exhaustive account of all optical, physical, or chemical techniques that have been proposed in the literature, but rather to provide a consistent and optimized set of techniques that have shown good potential in operational casework.

Chapters 5 and 6 bring the book to its conclusion. They provide the reader with an insight into fingerprint-related matters such as age determination, forgeries, and the management of errors. We also made an attempt at setting a standard nomenclature. In developing this book, we have made some choices that the reader needs to be aware of. First, we decided to give no account of the history of the use of fingerprinting in criminal investigation. We consider that the chapter from John Berry and the relevant section in David Ashbaugh's book are very complete accounts for fingerprint examiners (Ashbaugh 1999; Berry and Stoney 2001). In addition, recent publications have covered these historical aspects and brought to the table important sociological perspectives (Cole 1998, 1999, 2001), reaffirmed the contribution of Dr. Henry Faulds (Beavan 2001), and documented the essential development of the method in India during the nineteenth century and its influence in Britain (Sengoopta 2003). Although the reader will find significant material in the aforementioned references, we strongly felt the need to complement this view by presenting a European perspective that remains largely unknown and poorly documented. Among the active forensic scientists during the transition period between anthropometry (Bertillon) and dactyloscopy (Faulds, Galton, Henry, and Vucetich), little credit is generally given to Dr. Edmond Locard and Prof. R. A. Reiss. Locard (who later became head of the forensic science laboratory in Lyon) heralded from the famous medicolegal school of Lyon under the direction of Prof. A. Lacassagne. This group of researchers pioneered the optimization of detection techniques for bloodstains and fingermarks (Florence 1885; Coutagne and Florence 1889; Florence 1889; Frécon 1889). The early work of Galton became well known in France in 1891 through the publication of De Varigny (1891). Locard (1903) was immediately impressed by the simplicity and efficiency of dactyloscopy but was still hesitant to replace bertillonage. A thesis by France's Yvert (1904) gave Locard all the arguments necessary to push dactyloscopy forward. Locard then engaged himself in the review of all the systems of personal identification available at that time, covering Bertillon's anthropometry as well as the various dactyloscopic systems proposed worldwide (Locard 1909). This first book by Locard is a key contribution in the development of fingerprint science, providing a fair and comparative assessment of anthropometry and the dactyloscopic systems of Vucetich, on the one hand, and Galton-Henry, on the other hand. By 1909, Locard was convinced of the superiority of fingerprinting over anthropometry as a worldwide means of personal identification (Locard 1909). The between-user variability of recorded measurements was indeed one of the weakest points of anthropometry. The main debate at that time revolved around the efficiency of the classification system. Bertillon's system offered a versatile means of classifying hundreds of thousands of cards, whereas, at that time, fingerprints suffered from a lack of standardization. That view was held by Bertillon himself, followed by R. A. Reiss (1909a,b,c). There was no doubt that fingermarks offered a fantastic tool for criminal investigation (as Faulds first suggested), but the application of fingerprinting as the only record for personal identification was initially viewed with skepticism. Bertillon is often portrayed as a dogmatic opponent to the development of fingerprint identification. We believe that the reality is more subtle. Bertillon, in fact, embraced fingerprints very early and recorded fingerprints on the anthropometric cards from 1894. Around 1900, Bertillon worked on the development of easy and efficient detection techniques for revealing fingermarks at crime scenes. Indeed, Bertillon is known for one of the first identifications, that of a murderer, based on marks secured with powder at the crime scene; the Scheffer case (October 10, 1902) is known as the earliest conviction (March 15, 1903) for homicide in Europe that relied on fingerprint evidence (Sannié 1950). In 1903, Bertillon produced a classification system very close to the Vucetich system, and he suggested using fingerprints as a subsidiary (to anthropometry) classification system. Bertillon did indeed publish the now-infamous prints modified to display what could be viewed as 16 points in agreement (Bertillon 1912), but this publication was never intended by Bertillon to be a warning or a barrier against fingerprint evidence (Champod et al. 1993). Bertillon was forward looking, and despite his strong character and dedication to his anthropometric system, he contributed enormously to the development of fingerprinting as a new tool for identification purposes. The slow development of dactyloscopy is certainly due to the lack of international standardization regarding a classification system, whereas Bertillon's system was applied uniformly in the identification bureaus. This state of affairs was deplored by all the main actors during the sixth conference on criminal anthropology in Turin, Italy, in 1906, but we had to wait until the first conference devoted to police judiciaire in Monaco in 1914 to see some international resolution toward standardization (Roux 1926). (The proceedings of this meeting were published much later due to the First World War.) It is fair to say that international exchanges are still not fully optimized today. Although it is difficult to cover the development of fingerprinting in all countries, the work of Heindl (1927), a famous German dactyloscopist, deserves a special mention here. Heindl's book remains the most complete reference for its time (Heindl 1927).

The second option chosen for this book was to avoid a chapter on the development and use of automatic fingerprint identification/recognition systems. Nowadays, these systems are used operationally as very successful and decisive sorting devices, but they have no impact on the identification process itself. In other words, the identification of an unknown fingermark remains unaffected by whether or not the potential corresponding prints have been put forward to the fingerprint expert through a *standard* police inquiry or following a search within a database of millions of fingerprint records. Of course, this is not to say that automatic techniques have no impact on fingerprint matters; they represent decisive tools for the criminal justice system, moving fingerprint bureau practices from a few "cold hits" a week to dozens a day. In addition, we believe that automated processes will contribute significantly to the validation of the field in the very near future. Interested readers should refer to the historical accounts by Foote (1974) and Moore (1991). Surveys describing relevant research and the implementation of automated systems have recently been published, respectively, by Peterson (1996) and by Jain and Pankanti (2001), and recent books and dissertations portray a very active research community (Hong 1998; Jain et al. 1999b; Prabhakar 2001; Bazen 2002; Maltoni et al. 2003). Fingerprint technology cannot be separated from other biometric systems that are receiving very close attention nowadays (Jain et al. 1999a), and in the future, we will undoubtedly see the development of integrated systems combining multiple characteristics (e.g., fingerprints, DNA, face, and voice).

Finally, we express our gratitude to all those who have provided assistance and advice in the elaboration of this book. Our special thanks to Alexandre Anthonioz, David Ashbaugh, Les Bush, Nicole Egli, Eric Sapin (author of the photographs illustrating Section 3.6), Kasey Wertheim, and James Robertson.

Our thanks also to our respective families for their patience and understanding while this book was being put together.

Lausanne, Switzerland and Canberra, Australia

REFERENCES

Ashbaugh, D. R. (1999), Chapter 2: History of friction ridge identification, *Qualitative–Quantitative Friction Ridge Analysis—An Introduction to Basic and Advanced Ridgeology*, Boca Raton, FL: CRC Press, pp. 11–60.

Bazen, A. M. (2002), *Fingerprint Identification—Feature Extraction, Matching and Database Search*, Enschede, the Netherlands: Twente University Press.

Beavan, C. (2001), *Fingerprints—The Origins of the Crime Detection and the Murder Case That Launched Forensic Science*, New York: Hyperion.

Berry, J. and Stoney, D. A. (2001), The history and development of fingerprinting, in *Advances in Fingerprint Technology*, 2nd ed., eds. H. C. Lee and R. E. Gaensslen, Boca Raton, FL: CRC Press, pp. 1–40.

Bertillon, A. (1912), Notes et observations médico-légales—les empreintes digitales, *Archives d'anthropologie criminelle, de médecine légale et de psychologie normale et pathologique*, 27, 36–52.

Champod, C., Lennard, C., and Margot, P. A. (1993), Alphonse Bertillon and dactyloscopy, *J. Forensic Ident.*, 43, 604–625.

Champod, C. and Margot, P. A. (1997), Marks and impressions, in *Proceeding of the 11th Interpol Forensic Science Symposium*, Lyon, France: Forensic Sciences Foundation Press, pp. 161–182.

Champod, C. and Margot, P. A. (1998), Fingermarks, shoesole impressions, ear impressions and toolmarks: A review (Sept. 1995–Aug. 1998), in *Proceeding of the 12th Interpol Forensic Science Symposium*, Lyon, France: Forensic Sciences Foundation Press, pp. 303–331.

Cole, S. (1998), Witnessing identification: Latent fingerprinting evidence and expert knowledge, *Soc. Stud. Sci.*, 28, 687–712.

Cole, S. (1999), What counts for identity? The historical origins of the methodology of latent fingerprint identification, *Sci. Context*, 12, 139–172.

Cole, S. (2001), *Suspect Identities: A History of Fingerprinting and Criminal Identification*, Cambridge, MA: Harvard University Press.

Coutagne, H. and Florence, A. (1889), Les empreintes dans les expertises judiciaires, *Arch. anthrop. crim. et des sciences pénales*, 4, 25–56.

De Varigny, H. (1891), Les empreintes digitales d'après Galton, *Revue Scientifique*, 17, 557–562.

Florence, A. (1885), *Les taches de sang, leur signification en médecine judiciaire*, PhD thesis No. 256, Faculté de médecine, Lyon, France.

Florence, A. (1889), Les taches de sang, leur signification, leur importance en médecine judiciaire, *Arch. anthrop. crim et des sciences pénales*, 19.

Foote, R. D. (1974), Fingerprint identification: A survey of present technology, automated applications and potential for future development, *Criminal Justice Monograph*, Vol. 5, No.2, Institute of Contemporary Corrections and the Behavioral Sciences, Sam Houston State University, Huntsville, TX.

Frécon, A. (1889), *Des empreintes en général*, PhD Thesis, Imprimerie Storck, Bibliothèque d'anthropologie criminelle et des sciences pénales, Lyon, France.

Heindl, R. (1927), *System und Praxis der Daktiloskopie*, 3rd ed., Berlin and Leipzig, Germany: Walter de Gruyter & Co., Vereinigung Wissenschaftlichen Verleger.

Hong, L. (1998), *Automatic personal identification using fingerprints*, PhD thesis, Michigan State University, Computer Science and Engineering, Chicago, IL.

Jain, A. K., Bolle, R., and Pankanti, S. (eds.) (1999a), *Biometrics—Personal Identification in Networked Society*, Norwell, MA: Kluwer Academic Publishers.

Jain, A. K. and Pankanti, S. (2001), Automated fingerprint identification and imaging systems, in *Advances in Fingerprint Technology*, 2nd ed., eds. H. C. Lee and R. E. Gaensslen, Boca Raton, FL: CRC Press, pp. 275–326.

Jain, L. C., Halici, U., Hayashi, I., Lee, S. B., and Tsutsui, S. (1999b), *Intelligent Biometric Techniques in Fingerprint and Face Recognition*, Boca Raton, FL: CRC Press.

Locard, E. (1903), La dactyloscopie: Identification des récidivistes par les empreintes digitales, *Mém. Acad. Sci. Lyon*, 7(3ème série), 147–161.

Locard, E. (1909), *L'identification des récidivistes*, Paris, France: A. Maloine.

Maltoni, D., Maio, D., Jain, A. K., and Prabhakar, S. (2003), *Handbook of Fingerprint Recognition*, New York: Springer-Verlag.

Margot, P. and Lennard, C. (1994), *Fingerprint Detection Techniques*, 6th revised edition Lausanne, Switzerland: Institut de Police Scientifique et de Criminologie, Université de Lausanne.

Margot, P. and Lennard, C. J. (1993), Traces et empreintes: Le point sur les nouvelles techniques, *Revue Internationale de Police Criminelle*, 48(441), 10–18.

Meuwly, D. and Margot, P. A. (2001), Fingermarks, shoesole and footprint impressions, tire impressions, ear impressions, toolmarks, lipmarks and bitemarks: A review (September 1998–August 2001), in *Proceeding of the 13th Interpol Forensic Science Symposium*, D1, eds. R. E. Tontarski, Washington DC: US Department of Justice, pp. 1–52.

Moore, R. T. (1991), Automatic fingerprint identification systems, in *Advances in Fingerprint Technology*, eds. H. C. Lee and R. E. Gaensslen, New York: Elsevier Science Publishing Co., Inc., pp. 163–191.

Olsen, R. D. (1978), *Scott's Fingerprint Mechanics*, Springfield, IL: Charles C. Thomas.

Peterson, J. L. (1996), The status of AFIS systems worldwide: Issues of organizations, performance and impact, in *Proceedings of the International Symposium on Fingerprint Detection and Identification*, eds. J. Almog and E. Springer, Ne'urim, Israel, June 26–30, 1995: Israel National Police, pp. 233–254.

Prabhakar, S. (2001), *Fingerprint classification and matching using a filterbank*, PhD thesis, Michigan State University, Computer Science and Engineering, Chicago, IL.

Reiss, R. A. (1903), *La photographie judiciaire*, Paris, France: C. Mendel.

Reiss, R. A. (1909a), Les méthodes modernes d'identification de criminels, *Wissen und Leben*, 15 Janvier, 338–345.

Reiss, R. A. (1909b), Les méthodes modernes d'identification de criminels II. La fiche dactyloscopique, *Wissen und Leben*, 1 février, 385–389.

Reiss, R. A. (1909c), Les méthodes modernes d'identification de criminels III. Le portrait parlé, *Wissen und Leben*, 15 février, 439–452.

Roux, J. A. (1926), *Actes du premier congrès de police judiciaire internationale*, Paris, France: Marchal et Billard, G. Godde succ.

Sannié, C. (1950), Alphonse Bertillon et la dactyloscopie. L'affaire Scheffer, *Revue internationale de police criminelle*, 5(41), 255–262.

Sengoopta, C. (2003), *Imprint of the Raj—How Fingerprinting Was Born in Colonial India*, London, U.K.: Macmillan.

van Koppen, P. J. and Crombag, H. F. M. (2000), Oren, lippen en vingers: De waarde van oud en nieuw identificatiebewijs, *Modus*, 9(4), 28–32, 75, 6–12.

Yvert, A. (1904), *L'identification par les empreintes digitales palmaires (la dactyloscopie)*, Thèse de doctorat, A. Storck et Cie Ed., Lyon, France: Université de Lyon.

Authors

Christophe Champod received his MSc and PhD (*summa cum laude*), both in forensic science, from the University of Lausanne, Switzerland, in 1990 and 1995, respectively. He remained in academia until holding the position of assistant professor in forensic science. From 1999 to 2003, he led the Interpretation Research Group of the Forensic Science Service (United Kingdom) before returning to Switzerland to take up a full professorship position at the School of Criminal Justice (ESC; Ecole des sciences criminelles), University of Lausanne. He is currently in charge of education and research on identification methods and maintains an activity as an expert witness in these areas. He is a member of the Steering Committee for the International Fingerprint Research Group (IFRG) and a past member of Scientific Working Group on Friction Analysis, Study and Technology, and since 2014, he has been an invited member of the Friction Ridge Subcommittee (part of the Physics and Pattern Evidence Scientific Area Committee) of the Organization for Scientific Area Committees. In 2015, he received the European Network of Forensic Science Institutes (ENFSI) Distinguished Forensic Scientist Award for his contribution to forensic science. His research is devoted to the inferential aspects associated with forensic identification techniques. The value to be attached to fingerprint evidence is at the core of his interests.

Chris Lennard holds a PhD in chemistry (forensic science) from the Australian National University, Canberra—awarded for research into amino acid–specific reagents for fingermark detection on paper substrates. He took up a postdoctoral position with the School of Forensic Science at the University of Lausanne, Switzerland, in 1986 and became an associate professor in criminalistics at that university in 1989. He returned to Australia in 1994 to work for Forensic Services, Australian Federal Police (AFP), initially as laboratory services coordinator (1994–2002) and then as forensic operations support manager (2002–2006). In this latter role, he was the chief scientist, responsible for coordinating research and development across the organization's forensic science portfolio. In 2006, he moved to the University of Canberra and took up the role of professor of forensic studies (head of discipline). After eight years in that position, he relocated to Sydney in 2014 to run the forensic science program at Western Sydney University at their Hawkesbury Campus, Richmond. Over his career, he has maintained a strong interest and involvement in fingerprint-related research, particularly with respect to fingermark detection and enhancement techniques, with an extensive publication record in this area. He is a Steering Committee member for the IFRG, and he played a major role in the establishment of IFRG guidelines for the assessment of fingermark detection techniques.

Pierre Margot fell early into the cauldron of forensic science by earning a combined degree in forensic science and criminology from the University of Lausanne, Switzerland, in 1974. A short spell in the United Kingdom attracted him to pursue an MSc followed by a PhD in forensic science at Strathclyde University in Glasgow. Postdoctoral research led him from Salt Lake City (United States) in forensic toxicology at the Center for Human Toxicology (University of Utah), to the Federal Institute of Technology (EPFL) in Lausanne (research in chromatography), and then to the Australian National University in Canberra (Australia) to pursue research and development in dactyloscopy. He returned to Switzerland in 1986 to take up a professorial position at the University of Lausanne. He was the fourth professor occupying what was the first academic chair in forensic science, created in 1909. One of his major contributions is the creation of a research center where more than 60 PhD theses have been completed over the last 20 years, with a full commitment to further develop this center as a key contributor in areas that include forensic intelligence, investigative science, and the provision of solid and measurable evidence in court. His group has published more than 220 peer-reviewed papers in forensic science within the last 10 years. His contributions to forensic science have been internationally acclaimed, with major awards such as the Douglas M. Lucas Medal of the American Academy of Forensic Sciences, a doctorate honoris causa at the University of Québec in Trois-Rivières (Canada), accession to the French-speaking Pantheon of Criminalistics, and an ENFSI Distinguished Contributor Award. He is an associate editor of *Forensic Science International*, the major scientific journal in forensic science.

Milutin Stoilovic received his bachelor's and master's degrees at Belgrade University. In June 1980, he immigrated to Australia. From September 1980 till December 1989, he worked at the Australian National University in Canberra and was involved in fingermark detection research and the application of light sources in forensic science. His innovative work on the development of a forensic light source led to the eventual commercialization of the Polilight. In August 1990, he joined the Australian Federal Police (AFP), where, among other duties, he continued to research fingermark detection methods and optical enhancement techniques. He was involved in designing and evaluating a vacuum metal deposition unit that was built in Melbourne by the company Dynavac, specifically for the AFP. He has conducted numerous workshops on advanced fingerprint detection and enhancement and the application of optical methods for various forensic science disciplines. He has authored or coauthored more than 40 articles in this field. He retired from the AFP in 2008.

Contents

1 Friction Ridge Skin and Prints

The aim of this chapter is to provide a summary of the basic elements of friction ridge skin morphogenesis and their relationship to friction ridge skin variability. More extensive accounts for fingermark examiners can be found in the literature (Ashbaugh 1999; Bush 2002; Wertheim and Maceo 2002; Maceo 2011; Wertheim 2011). These contributions, with their associated references, constitute the essential material required to gain an understanding of the biological basis for friction ridge pattern variability. They complement and extend the work undertaken by earlier pioneers such as Wilder and Wentworth (1932) and Cummins and Midlo (1961).

Two cornerstones to the use of fingerprints as a means of personal identification are the overall permanence (a.k.a. persistency, durability, or reproducibility) and the high selectivity (a.k.a. discrimination) of friction ridge skin. It is thanks to these two attributes, and to the fact that fingerprints can be classified with relative ease, that the technique imposed itself over precedent identification methods based on anthropometric measurements. Both of these foundations—permanence and selectivity—have been challenged and confirmed through 100 years of fingerprint identification practice and their scientific foundations lie within biological research.

Unless examiners have a good understanding of friction ridge skin morphogenesis (the biological development of form), the basic tenet for individuality is, unfortunately, often resolved by using standard, shallow statements such as "nature never repeats itself" (McRoberts 1996). We strive to avoid a justification for individualization that only revolves around the tautological argument that every entity in nature is unique. The permanence and selectivity of friction ridge skin should be fully understood from a biological perspective and then applied in assessing fingermark comparisons.

1.1 STRUCTURE OF THE SKIN

Skin is an essential organ of the human body. Finger, palm, and sole areas of the epidermis display a series of friction ridges taking various forms and shapes. These volar areas of the skin are known to display friction ridge skin. Depending on the surface considered, we generally refer to them as fingerprints, palm prints, and soleprints. It is postulated that the essential function of having friction ridge skin is to increase grip.

The skin is usually divided into two distinct layers. The outer layer (Figure 1.1), called the epidermis, is a stratified epithelium of five sublayers, listed as follows from bottom to top:

1. Basal generating layer (*stratum germinativum*)
2. Spinous layer (*stratum spinosum*)
3. Granular layer (*stratum granulosum*)
4. Transitional hyalin layer (*stratum lucidum*)
5. Horny cornified layer (*stratum corneum*)

The layers of the epidermis are named on the basis of microscopic shape of the keratinocyte cells that constitute them. The layer under the epidermis is called the dermis and is 15–40 times thicker than the epidermis and constitutes the primary mass of the skin. The cornified layer exposed to the environment is made up of 15–20 layers of flat dead cells that are regularly shed through abrasion and replaced by keratinization. All these cells originate from initial cuboidal-shaped cells formed