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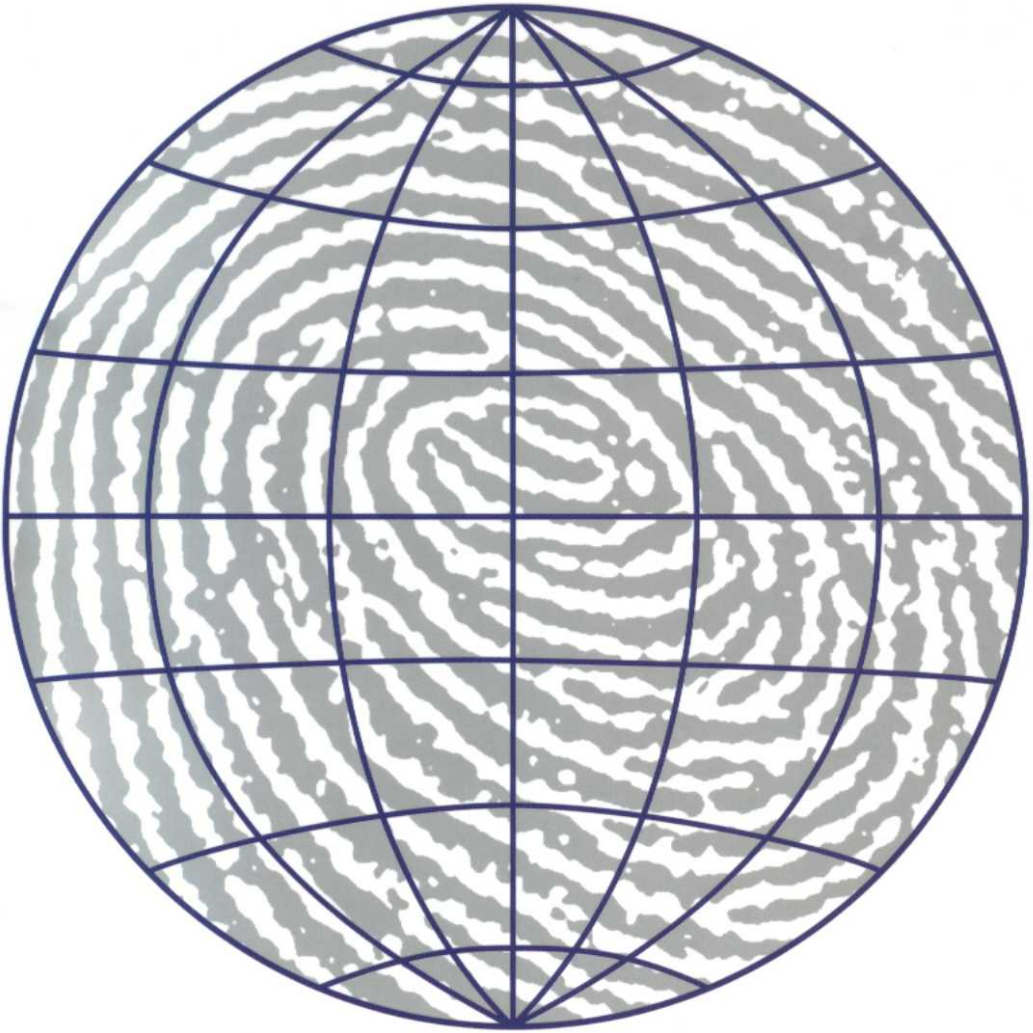
QUAERITE ET INVENIETIS



Objectives and Scope

Fingerprint Whorld is a quarterly peer-reviewed journal that reflects the aims of *The Fingerprint Society*, which are to advance the study and application of fingerprints and to facilitate the cooperation among persons interested in this field of personal identification.

It is devoted to the theory and practice of fingerprint identification science and its associated disciplines. To assist the aims, **Fingerprint Whorld** recognises that its membership is international and multi-disciplinary and as such sees a need for both new and review articles across the spectrum of forensic science evidence-gathering topics to assist in the continual professional development of all stages of the profession

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COMMENT

Graham Hughes, FFS

Ten years ago I took over the editorship of *Fingerprint Whorld* from the erstwhile John Berry. He promised me riches of all kinds, *"people from all over the world will just happen at your door"* to *"you will be asked on everything to do with fingerprints and you will learn a great deal"*. Well, the former did not really happen although in an abstract way it did. Many people from all over the world have contacted me for various reasons; appearing in the flesh they did not, by letter, fax, phone and lately by email, they did – some have even become very dear and valued friends.

Soon after I took over from John Berry I received a letter from an expert in Fiji saying that he was honoured to be a part of *The Fingerprint Society* and that he would like to offer his congratulations on my taking up the post of Editor. What touched me by his letter was the deep sense of courtesy in his words, full of humility and sincerity, and his parting phrase was *"I wish you well in your endeavours and may the Lord bless you sir."* I have kept this letter because I value sincerity in people, some have more than others – some have none. I hope that those who have known me as a person, be it expert, editor or friend, found some of that virtue in me.

Those ten years have flown by, more so, I suppose, by having to keep an eye on deadlines four times a year and constantly thinking how *Fingerprint Whorld* can improve. All in all, it has been a labour of love and a great source of pride. I have found new skills and applied them and have taken our publication from a society "magazine" to a peer-reviewed scientific journal of no mean repute. *Fingerprint Whorld* is now a very recognisable and tangible asset for *The Fingerprint Society*. However, as the walrus said, "the time has come...to think of many things, of shoes and ships and sealing wax, of cabbages and kings". Ten years is a long time to be in post and there needs to be a fresh perspective on things – a new editor. I cannot promise riches but I can promise support and hope in all things new for my successor.

One of the most important aspects of the post is that it gives exposure to new perspectives; it provides a medium in which to discuss and debate the profession and it gives a sense of belonging to something worthwhile. What it asks for in return is dedication, motivation, professionalism and education. The most important is the latter – education – for without this we may simply become automatons or even worse, dinosaurs. It is no secret that since the beginning of the 1990s I have read and agreed with David Ashbaugh in his treatise *"Ridgeology"*. I have taught it to novices in my bureau when I was a bureau trainer just to give them an outline of the truth behind fingerprint identification science.

There was a great deal of scepticism and criticism of the work and in some cases of Ashbaugh himself – was he a fingerprint person – did he have enough experience? He is not British – is he? I could see the value in his book and could even see the 16 point standard disappearing in favour of a non-numerical standard. Others could not and, indeed, would not accept the work preferring to cling on to the safety net of numbers even though they did not practice what they preached. The mistake would always come from somebody else somewhere in the country – but not in their bureau. I had a communication recently from a trainer overseas who has a pedigree in fingerprint experience. He told me that he did hold the British system in high esteem but not any more. How, I wonder, if this is the case with many other examiners around the world, will the UK ever return to its former status. The mistake, I think, has been in underestimating the expertise of other countries. The exposure to the worldwide fingerprint community has afforded me an insight into global expertise. The reticence of UK examiners to accept *Ridgeology* as a viable and beneficial work to the fingerprint profession has been because of the practice of parochialism in fingerprint matters. We are no longer the centre of fingerprint expertise and we should now work with other countries to learn from one another.

In Liverpool, March 2000, at *The Fingerprint Society Lectures*, we had the privilege to listen to the most articulate and professional explanation of the fingerprint identification system ever professed and it did not come from any UK expert. I would have given anything to have been present at the Daubert Hearing when Steve Meagher from the FBI gave his presentation on the fingerprint identification process. An astute expert and great friend confided in me soon after the hearing that Steve Meagher was magnificent and I believe him for Steve gave us all in Liverpool a lesson in clarity, expertise and professionalism. There was no expert in the UK who could have given that presentation and he did it all without the aid of a safety net – numbers. A court would have grasped the essence of fingerprint identification and more importantly understood the system with all its vagaries. Ashbaugh's work has come home to roost and experts would now benefit from its research. He may not be the world's best fingerprint expert just as Newton was not the world's best scientist but the thing that Ashbaugh and Newton have in common is that they discovered, through observation and research, a truth in their respective disciplines.

The realisation that something radical was going to happen first came to me when I was invited to Israel in 1995. The consensus of opinion was that the numerical standard was not going to last and the views expressed by the world's experts seemed to confirm this. Still, in the UK there was much cynicism from the least progressive of examiners and the debate was taken further until the present day. Fingerprint experts will have to be just that – experts – and they will have to be more adept at explaining the process of identification. I would expect all experts to be as good as Steve Meagher but that is asking too much but, given time, training and, above all, confidence, this may begin to happen.

As for me, I have moved into academia of a different kind which is proving as interesting as fingerprints first did all those years ago. It is strange that I am now having to do what fingerprint examiners should have been made to do in the past – research, write and cite. I can see the importance of learning and education (even though I have stressed these necessities before) and realise that to push oneself to find out more really does have a beneficial effect. I am indebted to *The Fingerprint Society* for allowing me the freedom to compile *Fingerprint Whorld* and making me write four times a year and more; writing skills are worth their weight in gold. I am also grateful for having had the opportunities to acquire good design and organisational capabilities which I am now putting to good use. All in all, I now know what I have missed being a fingerprint expert and I only wish I could pass this knowledge on in a more tangible form. I can only give advice and that is that examiners should practice their writing skills and be prepared to publish aspects of their work and research. Unfortunately, the greatest barriers to this course of action are peer pressure and a lack of focus on written contributions within the fingerprint profession; this is why there are so many people outside of the discipline willing to pass comment on what fingerprint examiners do and what they see as the failings of fingerprint identification science.

I hope that I have served this Society well in the past ten years and that the journal (Ray Broadstock please note the terminology!) has progressed to one that is awaited each quarter by all members – maybe not with baited breath but at least with some modicum of professional pride because *Fingerprint Whorld* is *your* publication and given *your* input and support will continue to assist in *your* professional development and education.

I would like to take this opportunity to thank Steve Haylock for his support and confidence in me as his Editor and to Ken Luff and Ray Broadstock before him; to members of the Committee for their friendship and trust; to all those people from around the world whom I have been glad to have as friends and colleagues. There are so many people with whom I have shared stories and good crack (colloq.) over the past ten years that I cannot mention you all but you know who you are – thank you.

Now, I can only echo an eighteenth century greeting given by a present-day Fijiian colleague and use it for *The Fingerprint Society* – *"I wish you well in your endeavours and may the Lord bless you sir!"*

SCIENCE

A PROBABILISTIC APPROACH TO FINGERPRINT EVIDENCE

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INTRODUCTION

The pursuit of forensic fingerprint identification is considered, by a broad corpus of opinion, to merit the status of a *science*.[1] Although we do not take issue with this view as a matter of principle, we wish to discuss how it impinges on current practice. We believe that there is, at present, a major contradiction between the scientific status that is claimed and the operational paradigm to which its practitioners subscribe. This contradiction is exemplified by a recent statement by the North American working group on fingerprint identification (**S**cientific **W**orking **G**roup on **F**riction **R**idge **A**nalysis, **S**tudy and **T**echnology – SWGFAST):

"Friction ridge identifications are absolute conclusions. Probable, possible, or likely identifications are outside the acceptable limits of the science of friction ridge identification" [2, p. 432].

We will base our discussion on two closely related questions that arise from this mandate:

Is a statement of an "absolute conclusion" compatible with scientific reasoning?
Is the denial of probabilistic reasoning compatible with a scientific pursuit?

After a short digression on terminology, we will illustrate the difference between deductive and inductive reasoning within the forensic context. Next we will discuss the desirability of trends throughout the forensic sphere towards *transparency* of opinions. After contrasting the perspectives of statistics and intuition we will explore a paradox that now exists within forensic practice following the introduction of statistically based DNA profiling evidence. Finally, we will return to the struggle between probability and "positivity" [3, 4].

DIGRESSION: A NOTE ON LANGUAGE

What distinguishes criminalistics from other sciences is that its practitioners not only aim to identify objects or persons as members of known classes, but they also aspire to individualise them as the single source of a recovered object or mark [5]. Criminalistics is defined as the *science of individualisation* and includes the science of fingerprint identification which is articulated around three principles: (1) the permanence and (2) the individuality of the human friction ridges and friction ridge skin arrangements, and (3) the capacity to achieve

[1] The main dedicated monograph of the FBI is entitled: *The Science of Fingerprints* [1]. During a recent Daubert hearing on fingerprint evidence (*U.S. v. Mitchell*, US District Court for the Eastern District of Pennsylvania, Criminal [No. 96-00407]), the Government put all its efforts to demonstrate that the field was scientific. The Government's memorandum can be found on the Internet: www.onin.com/pf/

individualisation following a systematic comparison of friction ridge skin or impressions containing a sufficient quality (clarity) and quantity of unique friction ridge detail.

In the fingerprint field, the term *identification* is used synonymously with *individualisation*. It represents a statement of certainty that a particular mark was made by the friction ridge skin of that particular person.[2] This is the sense in which we will use the word identification in this paper.

Another small item of terminology should be noted here. We will use the convention that UK practitioners follow of denoting the imprint of friction ridge surface recovered from a scene of a crime as a *mark* and that taken under controlled conditions from a suspect as a *print*.

Whenever a mark and print are compared there may be similarities and there will always be differences of detail, even if mark and print are from the same region of friction ridge skin. When the differences are such that the expert considers that they are within the acceptable range of differences to be expected between marks/prints of the same region then we will say that the mark and print are *indistinguishable*. Also, it is convenient to refer to such an outcome as a *match*. The match covers agreement at various levels, depending on the clarity of the mark, that may be classified as: level 1 – the general flow of the ridges; level 2 – the types and relative positions of the minutiæ; level 3 – pore structure and ridge detail. The decision about whether or not there is an identification will depend on the amount of corresponding detail that is present.

Finally, we note that considerable confusion exists among laymen, indeed amongst forensic scientists also, about the use of words such as *unique*; *identical*; and *identity*. Although the phrase "all fingerprints are unique" has been used to justify fingerprint identification opinions, it is no more than a statement of the obvious. Every entity is unique; no two entities can be "identical" to each other because an entity may only be identical to itself. Thus, to say "this mark and this print are identical to each other" invokes a profound misconception: they might be indistinguishable but they cannot be identical. In turn, the notion of indistinguishability is intimately related to the quantity and quality of detail that has been revealed. The question for the scientist is not "are this mark and print identical" but, "given the detail that has been revealed and the comparison that has been made, what inference might be drawn in relation to the propositions that I have set out to consider".

DEDUCTION AND INDUCTION IN FORENSIC SCIENCE

In this section, we explore the inferential process of identification and to demonstrate that is essentially inductive and hence probabilistic.

Consider a hypothetical case in which a mark left at the scene of a crime must have been left by the friction ridge skin of a person from a closed group of individuals (perhaps the passengers and crew of a cruise ship in mid-ocean or more fancifully, the crew of an interplanetary space cruiser). X is suspected of having committed the crime, his prints are taken and that from his right thumb is found to match the mark from the scene. To interpret this match, there are two propositions, or hypotheses, to address:

C: The mark was left by X.
C: The mark was left by another person from the population of suspects.

One way of addressing the inferential problem would be to take the prints of every person in this closed "universe". Assume that this is done and that the prints of all of the other suspects were found to be different from the mark. We can now view this as a problem based

[2] According to Tuthill: *The individualisation of an impression is established by finding agreement of corresponding individual characteristics of such number and significance as to preclude the possibility (or probability) of their having occurred by mere coincidence, and establishing that there are no differences that cannot be accounted for."* [6 p. 21].

on three premises:

(1) The mark was left by an area of friction ridge skin of one of the members of the population.
(2) The mark cannot be distinguished from the right thumb of X.
(3) The mark has been found to be different from all friction ridge skin areas of every other member of the population.

Now, *if* we accept the truth of each of these three statements then it necessarily follows that the mark was left by X. This is a deductive argument. *If* premises 1, 2, 3 are true, then it is certain that proposition *C* is true. This is not a probabilistic statement – it satisfies all of the requirements of "positivity". This is deductive reasoning, seen to be the hallmark of the great fictional detectives such as Sherlock Holmes.

Let us now move from the carefully restrained initial problem to the second where there is an "open" population of suspects: the crime was committed in some city in which there is, potentially, a large and imprecisely defined group of people who might have committed the offence. Again, there is a suspect, X, whose right thumb print matches the crime mark. An entirely hypothetical approach to resolving this problem would be to take prints from every single man, woman and child in the planet and eliminate all of them, other than X. Then it would be possible to follow the same deductive reasoning as in the first example and conclude with certainty that the mark was left by X.

Of course, such an approach is unrealistic. It appears difficult to comprehend the day when it would ever be feasible, or even desirable, to screen the entire planet. So now we approach the reality of everyday forensic investigation. We cannot consider the entire population of suspects – the best we can do is to take a *sample*. The mechanism of the sampling is not important here but the principle that follows is fundamental. We use our observations on the *sample*, whether formal or informal, to draw inferences about the *population*. No matter how large our sample, it is not possible for us to say that we have eliminated every person in the population with certainty. It is not possible to make certain statements about a population based on observations on a sample: this is the classic scientific problem of *induction* that has been considered in the greatest depth by philosophers. Whereas philosophers are divided in their views of induction it is inescapable that we cannot make the statement about the open population of the entire planet that we could make in our first example, where there was a closed population.

If we wish to address an open population then probabilistic statements are unavoidable – indeed, this is the notion of the entire discipline of statistics.

So there are two main differences between this second example and the first, where deduction was possible: first, the population is imperfectly defined (we return to this later); second, whatever the population, we can only make probabilistic inferences in relation to it.

The two propositions that we addressed in relation to the first example now become:

C: The mark was left by X.
C: The mark was left by some unknown person.

The three premises that we made in relation to the first example now become something along the lines of:

(1) The mark was left by an area of friction ridge skin from a person from an imprecisely defined population.
(2) The mark is indistinguishable from the right thumb of X.
(3) The probability that there is another person whose friction ridge skin area would be found to be indistinguishable from the mark is very small.

Now the inference in relation to the starting propositions must be probabilistic. We recognise that the probability is necessarily personal, because it incorporates the belief of the scientist that the model that he is using to draw inference is a good model.

Given that the probability is personal, we might now choose to take another step in which the scientist says "the probability that the mark was left by another member of the population is so small that I am prepared to discount it". We will later discuss the conditions under which the scientist might do this but, for the present, we re-iterate our point that the reasoning is essentially inductive and probabilistic as explored by Kwan [7]. The "certainty" that the scientist might aver in the final example is quite different in nature from the deductive certainty in the first example.

One attempt to remove a source of uncertainty from this latter open framework is to address the entire population of the world. For example, SWGFAST defined the identification as *"[...] the determination that two corresponding areas of friction skin impressions originated from the same person to the exclusion of all others."* [2, p. 431]. This implies the exclusion of all friction ridge skin surfaces on earth, other than the matching print. This view removes uncertainty about the definition of the population of suspects, but the issue of making inferences about the population from a sample is, of course, the same: indeed, it is exacerbated because the projection from sample to the world population is larger than if some smaller geographical restriction were made.

It is worth mentioning that we have problems with the notion of addressing the entire population of the world (see [8]). Not only is it an entirely hypothetical exercise; but also it makes little sense in relation to the investigation of the case at hand. For example, if the crime occurred in Huddersfield, England, does it really make sense to consider a two-year-old baby in Beijing a suspect for the offence? Invoking the "population of the world" argument is doing no more than providing an extravagant and entirely hypothetical illustration of the weight of the evidence.

TRANSPARENCY VERSUS OBSCURITY

We now explore in more detail how this inductive process is presented in court.

The traditional role of expertise in forensic science is well recognised and it is something of a stereotype to visualise the distinguished, greying individual on the stand saying, "my opinion is based on my many years of experience in this field". Whereas we do not for one moment deny the value of experience, we claim, as a matter of principle, that the scientist should, as far as possible, support his/her opinion by reference to logical reasoning and an established corpus of scientific knowledge. This is what we mean by "transparency"; the former "in my experience" justification we refer to as "obscurity". We have no doubt that courts prefer transparency to obscurity: one only has to study a few of the intensive *Daubert* hearings in the USA for evidence of that view. The recent hearing regarding fingerprint evidence in *U.S. v Mitchell*[3] is a case that we will refer to later.

However, transparency may be no more than an illusion. A classic case is the so-called "16 points[4] standard" that existed in the UK for some 80 years.[5]

Following a scrupulous procedure[6] for comparing a mark with a known print, suppose that a fingerprint examiner observes that there is a match. And then the fingerprint expert concludes that: *"this mark has been left by this forefinger to the exclusion of all other friction ridge skin"*. When questioned about the logical steps followed to reach this conclusion, an examiner in the UK would traditionally have answered: *"because there are 16 points in agreement without discrepancies between the mark and the print. Sixteen is the minimum number of points of agreement required for declaring an identification."*

Courts in the UK traditionally welcomed this apparent transparency and the "fingerprint" has become the gold standard by which other kinds of evidence are measured; hence, no doubt the early use of the confusing phrase "DNA fingerprinting". Again, we do not wish to take any issue with the high regard that the pursuit has enjoyed in the courts – our point is that the apparent transparency afforded by "16 points" was an illusion. There never was any scientific justification for the number; furthermore, as all practitioners will recognise, what is a "point" to one expert might not be a "point" to another [11].

Most fingerprint examiners recognise that the process of counting matching points up to a number determined by policy does not precede the identification: on the contrary, it is usually the case the expert reaches a state of personal conviction about the identification, based on a wide spectrum of features, *before* the point count is made. The process of gleaning sufficient points has been called "teasing the points" out in the UK fingerprints system and is discussed in more detail by Evett and Williams [11]. It is not reasonable to reduce the issue of fingerprint individuality to numbers of corresponding minutiæ alone. The nature of the papillary individuality prevents the adoption of any predefined number of ridge characteristics in agreement necessary for concluding to an identification. The identification process is a global assessment – balancing both quantitative (minutiæ) and qualitative (pores, edges) aspects visible on the mark.[7]

We applaud the contribution that Ashbaugh [10] has made to the establishment of fingerprint identification as a science. His is the kind of studies and arguments that form the bedrock of a corpus of scientific knowledge that any expert can draw on in explaining fingerprint individuality in court. However, when it comes to the core issue of drawing inference from what we, somewhat imprecisely, call a "match", Ashbaugh says: *"Finding adequate friction ridge formation in sequence that one knows are specific details of the friction skin, and in the opinion of the friction ridge identification specialist that there is sufficient uniqueness within those details to eliminate all other possible donors in the world, is considered enough"* [10, p. 103].

Here we get to the core of the matter. It is the expert who forms the opinion that there is "sufficient uniqueness...to eliminate all other possible donors in the world". Ashbaugh is not clear on how this inference is to be drawn: we have argued that it must be inductive. The expert is, however imprecisely, forming a view about the entire world when he cannot possibly have considered more than a sample. So the quotation from Ashbaugh illustrates two of our points: first, the opinion is based on inductive reasoning (it follows inevitably that it must be probabilistic); second, the process by which the expert arrives at his opinion is ultimately obscure. We will return to the first point. For the time being, we elaborate the second. The point is that Ashbaugh evokes the need to eliminate all other possible donors in the world, but does not say how it can be done – essentially this is because it *cannot* be done. Certainly it cannot be done by scientific means but even leaving science to one side, no one person can attain and

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[3] *U.S. v. Mitchell*, US District Court for the Eastern District of Pennsylvania, Criminal [No. 96-00407].

[4] 'Point', 'ridge characteristic', 'minutia', 'Galton point' are equivalent terms used to describe the major ridge path deviations. Ridges may bifurcate or stop forming bifurcations or ridge endings.

[5] We could have chosen the practice of any country requiring a pre-defined number of minutiæ (without discrepancy) to conclude to an identification. Paradoxically, these numbers vary among countries: e.g. 17 in Italy, 16 in the UK (until 2001), 12 in Holland, 8 to 12 in Germany or Switzerland [9].

[6] The mainstream protocol for comparison is summarised in the acronym ACE-V for **A**nalysis, **C**omparison, **E**valuation and **V**erification. Details can be found in Ashbaugh [10].

[7] For this reason, the International Association for Identification (IAI) took the following resolution: *"[The International Association for Identification], based upon a 3-year study by its Standardisation Committee, hereby states that no valid basis exists for requiring a predetermined minimum number of friction ridge characteristics that must be present in two impressions in order to establish positive identification."* [12, p.8]. This resolution has been recently reaffirmed [13, p. 21].

retain comprehensive knowledge of the prints of every person in the world. It has to be an inference, be it scientific (which it cannot be) or otherwise. The conclusion has to be, as Stoney [14] eloquently put it "a leap of faith": as such, it is ultimately obscure.

The conclusion of certainty derives from the examiner's personal conviction that the chance of a match between the crime mark and any person other than X is so small that it can be ignored. Effectively, the expert sets a personal threshold that rounds the probability assigned to the identification to 1. This position appears, through custom and practice, to be acceptable to courts in all situations where statistical analyses are not possible: fingerprints; handwriting; toolmarks; footwear; etc. But, in the UK at least, it is clear that where a statistical analysis is possible the burden of concluding moral certainty shifts from the expert to the jury. We return to this later.

INTUITION AND STATISTICS

There appears to be little disagreement that the identification decision is inherently subjective: *"The opinion of individualization or identification is subjective"* [10, p.103].

There has been quite some debate in the literature about subjectivity and objectivity. We should make clear here that we have no objection whatsoever to subjectivity. There is a view that "objective" equates to science and "subjective" equates to non-science.[8] This is not our view: indeed, we will explain later that subjectivity is an inescapable feature of science [16].

Returning to our inductive model. The fingerprint expert's reasoning is based on the idea that the probability that another person would match the mark (we will call this the *match probability*) is so small that it can be discounted. Greater transparency in this process is afforded if a match probability were assigned by means of a database that had been constructed from a suitable survey. There is little doubt that courts welcome such exercises. The introduction of DNA profiling has been accompanied by an extensive debate on the statistics of profiles and there is now a considerable body of literature on the subject. In *U.S. v Mitchell* statistical arguments were presented by prosecution, based on experimentation using the FBI automatic fingerprint identification system (AFIS).

With the extensive use of DNA – probability based – evidence and the evolving requirements for the admissibility of scientific evidence, older identification fields like fingerprints are becoming subject to more rigorous scrutiny and are under the pressure of a growing demand of scientific data [17-19] to underpin the identification of fingerprints. The recognition of the fingerprint field as a scientific domain seems deeply related to its capability to provide reliable statistical estimates of the rarity of identification features. Some commentators urge for acquiring statistical data related to fingerprints [20] and, although this need was recognised more than 50 years ago [21], very little research had been done. This lack has been recently recognised by the *National Institute for Justice* (NIJ) in the United States which has recently invited research proposals for potential funding.[9] We welcome this initiative but we feel that the objectives of such research have to be clearly defined. The NIJ aims to promote research to *determine the scientific validity of individuality in friction ridge examination based on measurement of features, quantification and statistical analysis*. The NIJ suggests that statistics can address the question of individuality and resolve the statistical basis of the identification process. In our opinion, this stated objective translates a common

[8] This view was recently adopted by the defence during two Daubert hearings in the United States: *U.S. v. Byron Mitchell*, US District Court for the Eastern District of Pennsylvania, [Criminal No. 96-00407] and *U.S. v. Hilerdieu Alteme et al.*, US District Court – Southern District of Florida – Fort Lauderdale Division [Case No. 99-8131-CR-FERGUSON]. All related documents can be obtained from http://www.onin.com.fp/ A short overview of the arguments in the Mitchell case can be found in Grieve [15].

[9] The relevant documents are available on the Internet: http://www.ojp.usdoj.gov/nij

misunderstanding of the potential of statistics to any individualisation problem. We agree with Grieve that attempting to demonstrate the individuality of fingerprints by statistics, especially with the virtual reality of statistical modelling is fruitless [22].

One of the most frequent questions asked of statisticians regarding fingerprints is of the kind: "If a comparison between a mark and a print shows a given set of features in agreement without discrepancies, could you demonstrate statistically the identity of source?" The quick answer is no as Stoney puts it: *"you cannot achieve individualization through statistics."* All that statistics can do is provide a model for assigning a match probability in a given case and provide guidance on setting that match probability in some kind of relevant population framework: the latter leading to some kind of inference to the probability of the mark and print being from the same person. But statistics can do no more, at the end of the day, than provide a probability. It is for others to decide on whether that probability is small enough to conclude identity of source, though the FBI appear to be promoting the view that a scientist may set a criterion for "certainty" – they suggest the phrase "reasonable degree of scientific certainty" [23, 24]. The use of the word "scientific" in this context implies an objectivity that is entirely illusory – scientific certainty is no different from any other kind of certainty.

But some may argue that the random match probabilities for fingerprints are so small that, whatever the framework, the probability of the identification will be so close to 1 that there is no need to disclose to the court any number. During the recent *Daubert* hearing in the *U.S. v Mitchell* case, the FBI provided calculations based on experiments done carried out on an AFIS system. For complete fingerprints, a random match probability of 10^{-97} was claimed. For partial marks, the match probability was given as 10^{-27}.

Such figures, at first sight, appear to relegate the argument that we are presenting to the status of nit-picking. But there is a wonderful subtlety about this that illustrates our point about "transparency". There must be a temptation on the part of the court to accept the numbers as real "statistical probabilities" that put the matter beyond argument. However, we need to dig deeper. Even with large experiments such as those in *U.S. v Mitchell*, we have to concede that we are doing no more than looking at a sample of prints. The way in which we draw inferences from that sample is, as we have explained, *inductive*: we wish to make a broader inference beyond what is contained in the sample. This is a perfectly legitimate pursuit – it is the core aim of the discipline of statistics. To do it, we need to use mathematical methods. To use mathematical methods we need to make assumptions: it is conventional to describe this as *modelling*. We can do a certain amount of studying, using our sample, or the validity, or *robustness* of our model but there are limits to our study that necessarily follow from the size of our sample.

The DNA profiling field gives a parallel illustration of this. Assume that a scientist, in a case in which there is a match between a crime profile and a suspect, tells the court that the match probability is one in a billion. Asked about the size of the database that has been used, he replies that it consists of 200 individuals. This naturally provokes the question "how can you quote such a minute probability when your sample is so small?". This is a good question – the answer is that the match probability is a kind of projection that is based on a set of assumptions that derive from extensive knowledge of the population genetics and statistics of the constituent parts of DNA profiles. In its simplest terms, the match probability comes from multiplying together a series of other larger probabilities. This necessarily invokes assumptions of statistical independence. In the world of DNA profiling, a large number of experiments have been carried out by varying practitioners and they suggest that the independence assumptions are robust enough to support match probabilities as small as one in a billion [25].

Not surprisingly, the extent to which the robustness of the independence assumptions can be investigated is a function of the size of the samples that are used. In very rough terms, the power of the study is a function of the number of between-person comparisons that the sample enables. Thus, for example, a sample of 1500 enables approximately one million comparisons

(actually, it is 1500 x 1499/2) and thus addresses robustness issues down to the order of match probabilities of one in a million.

Let us take the first of the figures that we quoted from *U.S. v Mitchell*. In the entire history of mankind, there have been only about 10^{11} fingerprints. So, even if we had them all in our computer, we could only investigate modelling assumptions supporting probabilities of the order 1 in 10^{22}. The figure of 10^{-97} so transcends reality that we are amazed that it was admitted into evidence. It is entirely unsupportable. This extraordinary number was obtained by a model-based formula that took the probability density of extreme points of a known distributional assumption: the weakness of this argument has been pointed out by Wayman [26]. It is not possible to establish the behaviour of the extreme of the tail of a distribution when the sample is only large enough to study the centre of the distribution.

So we should not have unrealistic expectations of statistical studies and the aim of quoting extravagantly extreme numbers is, ultimately, not productive. It follows that it is not possible to *prove* that a given mark must have been left by a particular region of friction ridge skin. The process is, as we have said, essentially inductive and absolute certainty is not logically attainable.

Nevertheless, this logical limitation does not prevent statistics from offering a highly powerful tool for assessing fingerprint evidence. Although limited statistical investigations [27-29] were made at the time that fingerprints were gaining acceptability, they were far too small and based on unrealistic assumptions to provide anything other than some peripheral support for the technique [30]. More recent studies [31-41] provided valuable knowledge but they could not be used to enable case-specific calculations. None of the proposed models have been subjected to extended empirical validation studies. The robustness of the independence assumptions at the core of each model have not been explored. Nor have the relationships with other variables such as sex or ethnic origin. The gap between DNA statistics and fingerprint statistics is huge.

Up to now, no statistical models have incorporated the various factors of individuality (general pattern, major ridge deviations, ridge edges or pores). The models simplify the complexity by adopting a restricted view on the overall factors, most of them being concentrated on the study of the statistical behaviour of minutiæ. However, the imperfection of any model does not preclude its use in fingerprint science if the robustness has been extensively demonstrated and submitted to scientific scrutiny. Statistical data even gathered through myopic models will provide in the future reliable and transparent assessments of the value of evidence.

FINGERPRINTS AND DNA

DNA profiling has been a significant milestone for forensic science – the first evidence type that has been introduced, and accepted by courts, through detailed statistical studies that enable numerical measures of evidential weight. The statistical debate of this new pursuit has been extensive, at times acrimonious and also stressful for some of the participants, but there appears to be universal agreement that it has been extremely beneficial to the science.

Courts expect that the expert will provide a statistic of some kind to express the evidential weight of a match between two profiles. This is a manifestation of what we earlier referred to as "transparency". The statistics that are quoted are often very small: with the current system in use in the UK, a full profile match between a crime stain and a suspect is assigned a match probability of the order of 1 in a billion. This has, almost inevitably, led to questions of the kind "how small does the probability have to be for the evidence to be as strong as a fingerprint". This issue has been discussed elsewhere [42], but from what has been already covered in this article we can see that the question has no simple answer.

In the UK indeed, the question has become somewhat superfluous because of the ruling of the Court of Appeal in *R v. Doheny, R. v. Adams* ([1997] 1 Cr App Rep 369):

The scientist should not be asked his opinion on the likelihood that is was the Defendant who left the crime stain, nor when giving evidence should he use terminology which may lead the Jury to believe that he is expressing such opinion.

We find this ruling reasonable. There is no conflict with the scientific view of the problem, though we recognise that there is a need for systems to be in place to provide the jury with the necessary guidance for combining the DNA evidence with the other non-scientific evidence. This is discussed in some detail in Evett *et al.*[42].

If we now take this analogy into the fingerprint field, the logical corollary is that, if one day it becomes possible to assign some numerical value to the weight of evidence to be assigned to a given comparison, then it is that number that should be given to the court – the expert opinion of individuality becomes superfluous. For fingerprint experts it would represent a profound culture change, but within the DNA field it presents no particular problem.

PROBABILITY VS POSITIVITY

The present state of affairs, then, is that fingerprint experts refuse to report opinions in terms of probabilities. This has been termed the doctrine of "positivity" – see, for example Knowles [4] and a recent associated comment [43]. All comparisons that fall between the extremes of definite inclusion and definite exclusion are classified as "inconclusive".[10] It is our view that much evidence is denied to courts because of this policy – a policy that is clearly incompatible with the probabilistic identification process we have outlined. In a case where, perhaps because of the limited quality (or clarity) of a mark, the weight of evidence is not sufficient to convince the expert of a categoric opinion, there may be corroborative evidence of less weight that might provide useful guidance to a court. This concept is recognised to be central to the reporting of other fields of forensic science, such as handwriting, toolmarks, footwear and so on.

Any court would wish to be informed of any evidence that can lead the fact finder closer to the truth even by a small degree. Fingerprints have already been considered by jurists from a probabilistic and corroborative point of view [45-47]. This issue has also been addressed by the Court of Appeal of New Zealand (*R v Buisson* [1990] 2 NZLR 542 (CA)) when the Court stated that much useful evidence was being kept out of the courts on decision of technicians [48]. A review of the origin of this policy can be found in Champod [49]. There appear to be three arguments that are constantly used by practitioners in its support.

The first argument stipulates that probabilities cannot be used in the field because of the individuality of friction skin arrangements. It takes the following form [50, 51]: *Any probabilistic statement would imply a potential for duplication. But individuality prevents any duplication. Hence probabilities does not apply to fingerprints.* It is axiomatic that no two fingerprints are identical – indeed, no two entities of any kind can be identical to each other – but the crux of the matter is not the individuality of the friction skin ridges but the ability of the examiner to recognise sufficient information for the disclosure of identity from a small-distorted latent fingerprint fragment, that may reveal only a limited information in terms of quantity or quality [52]. It is the examiner's capacity to reveal individuality from a papillary impression that is at question and not the individuality of the skin surface that produced it. The concept encapsulates a continuum of values in that an expressed feature of a mark may have the capacity to distinguish sources at various degrees depending on its clarity. These various degrees have a probabilistic nature.

[10] The International Association for Identification (IAI) took in 1980 the following resolution: "*[The delegates of the IAI] state unanimously that friction ridge identifications are positive, and officially oppose any testimony or reporting of possible, probable or likely friction ridge identifications found on hands and feet, [...]*" [44].

The second argument is that probabilistic opinions should be avoided until a dedicated tool for assessing match probabilities is made available to the examiner [53]. Whereas a cautious approach is to be commended, it presents a peculiar state of affairs. An opinion of individualisation means that the known individual is singularised with respect to the world population. But paradoxically, a fraction of second earlier in the process, when the information gathered is judged by the examiner as insufficient to individualise, it is suggested that the examiner cannot give any opinion. We think that this transition from no knowledge to certainty is not compatible with the logic of the inference of identity of source. If examiners are able to provide opinions regarding individualisation, they should also be able to provide answers regarding the value of possible associations.

The third argument is that the admission of probabilistic statements would weaken the concept of positivity. The perception is that the pursuit should be seen to be exact, with no shades of grey. But this is more a cultural view than one that has derived from any process of scientific reasoning. No doubt, most fingerprint experts see our arguments as a threat that could undermine the profession. That is not our intention. We have no dispute with the power and utility of fingerprint examination. Indeed, we seek to expand the potential of the pursuit.

RESUME

In the introduction we posed two questions, that we believe we have now answered.

Is a statement of an "absolute conclusion" compatible with scientific reasoning?
We have shown that the process of individualisation is essentially inductive and an absolute conclusion only follows if the expert is given the right, by the court, to conclude that the probability that there is another person who would match the mark at issue is so small that it can be ignored. This is more a legal, rather than a scientific, issue, because there is no scientific basis for a personal threshold. But it is clear from the DNA field that, once courts understand the process then, if probabilities can be calculated then they should be put before the court for the jury to deliberate.

Is the denial of probabilistic reasoning compatible with a scientific pursuit?
An inductive process must be probabilistic and denial of that state of affairs cannot be logical. If it is not logical, then it is not scientific.

We have also argued that transparency is preferable to obscurity. The future holds the promise of extensive experimentation on fingerprints data that will lead to the power to make calculations in individual cases. The prospects are enormously exciting but the fingerprint profession needs to be prepared for cultural change. The identification process as carried out today is obscure.

If match probabilities can be calculated for individual mark/print comparisons then the present arbitrary step from "inconclusive" to "conclusive" disappears. The way is open for presenting corroborating evidence in cases that, today, would not be presented at court. To deny the inevitability of this advancement is to deny the pursuit the status of "science".

CONCLUSION: BENEFITS AND LOSSES

The question might be posed – "why bother with any of this probability stuff?". After all, fingerprints identification as it is presently practised works superbly well in most jurisdictions and the standing of the pursuit, with which we take no issue, is extremely high. Opponents of change would adopt time-honoured maxims such as "it has stood the test of time" and "if it ain't broke, don't fix it". What are the pros and cons of change?

1) First, change in any pursuit is inevitable. This particularly applies if the pursuit is to be considered a science. The scientist does not say "I will do it this way because this is the way I have always done it", but "why do I do it this way?" and "could I do it better?". Such questions are the core of scientific progress.

2) Will the adoption of a probabilistic approach render the presentation of evidence more difficult? If adequately trained, fingerprint experts should have no more difficulties in presenting evidence in a transparent manner rather than defending obscure dogma. We recognise that training is the key issue in this respect.
3) Will evidence be given in a greater number of cases than at present? Yes, valuable evidence will be disclosed in an increasing number of cases. According to Knowles [4], "non-provable" identifications (identification declared without meeting the "standard" of 16 points) count for about 30% of the cases in some forces in the UK. Adopting a probabilistic approach should have a strong impact on how marks are selected and kept for further comparison.
4) Greater transparency is an essential added-value benefit of this approach.
5) The changes that we foresee would establish the pursuit as a science over and above its status as a profession. We echo a wish expressed by Paul Kirk in 1963 [5]. Paradoxically, it is perhaps precisely because fingerprint experts have not resolved the real issues surrounding the nature of fingerprint evidence and their own status, whether scientist or technician, that they have achieved their enormous credibility in the courtroom [54]. It is our wish that fingerprints should justifiably take its place within forensic disciplines as a true science: Science is not founded on dogma – its foundations are logical reasoning and reliable knowledge.

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FINGERPRINT DIAGONAL REVERSE SEQUENCE ARRANGEMENT

Andres J. Washington
Fingerprint Geometric Analysis

PURPOSE AND INNOVATIVE ASPECTS

This work provides a description of the *Fingerprint Diagonal Reverse Sequence Arrangement*. It is a geometric analysis based on the location(s) of a given fingerprint code. The first section of text describes how to apply the formula to a sequential chart. Next, the *Primary Classification* from the Henry System of Fingerprint Classification and Filing, which consist of 1,024 codes, is provided. The *Fingerprint Diagonal Reverse Sequence Arrangement* is applied to the primary classification sequence to create a *multi-sequential primary classification chart* in which an individual code can display up to three different locations. Each code will have a unique geometric design on the chart, a design that is triangular or linear in appearance. Once an identifiable design for a given code has been established, an analysis of that design as well as its geometric relationship to other codes and their design can be explored. Finally, *The Sequencing of Pattern Display* provides the entire list of numerical values that can be assigned to the ten digits for the primary classification.

If we were to attribute a classification code to the potential of an individual's personality geometrically, then it would be possible to discover why and how an individual may be like or unlike another. In addition, when teamwork is the endeavor, groups of classifications can be established presenting the complimentary aspect of people working together.

The original sequence found in section "A" is for the sixty-four possibilities when the # 2,3,4,7,8 and 9 fingers are considered; this sequence only includes the inner and outer loops. When a number is assigned to each box from left to right and working down to the last box # 64, box 64 would equal

ooo
ooo.

Due to the fact that the inked fingerprint is in actual reverse (*Mirroring*), it has been determined that if the sequence in section "A" was to be arranged to the sequence found in section "B" it would then be in reverse displaying a different perspective of the total possibilities in relation to each other. This diagonal reverse is then used to provide the arrangement of the *Second Reference Sequence* found in section "C".

The second reference sequence works as a verification in its outcome of how the first reference sequence was established. If the first reference sequence was not in proper arrangement then the second reference sequence would not be in a uniform sequencing pattern. A close examination of the fingerprint codes found in the second reference sequence reveals a definite pattern along a diagonal basis.

For further analysis, the second reference sequence has been divided into three areas; named area A, area B, and area C. In area "A" the extreme diagonal of each box contains its opposite code. In areas "B" and "C" the extreme diagonal of each box contains the same code in reverse.

Section "A" Original Sequence

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64

Figure 1A.

I I I I I I	IIO II I	IOI I II	IOO I I I	OII I II	OIO I I I	OOI I I I	OOO I I I
I II IIO	IIO IIO	IOI IIO	IOO I IO	OII IIO	OIO I IO	OOI I IO	OOO I I O
I I I IOI	IIO IOI	IOI IOI	IOO IO I	OII IOI	OIO I OI	OOI I OI	OOO I O I
I I I IOO	I IO IOO	IO I IOO	IOO IOO	OI I IOO	OIO IOO	OOI IOO	OOO I OO
I I I O II	IIO OII	IOI OII	IOO OI I	OII OII	OIO OI I	OOI O II	OOO O I I
I I I OIO	I IO OIO	I OI OIO	IOO OIO	OI I OIO	OIO OIO	OOI OIO	OOO O IO
I I I OOI	I IO OOI	I OI OOI	IOO OOI	OI I OOI	OIO OOI	OOI OOI	OOO OO I
I I I OOO	I I O OOO	I O I OOO	I OO OOO	O I I OOO	O IO OOO	OO I OOO	OOO OOO

Figure 1B.

Section "B" First Reference Sequence

1	9	15	21	25	29	31	64
56	2	10	16	22	26	63	32
50	55	3	11	17	62	27	30
44	49	54	4	61	18	23	28
40	43	48	60	5	12	19	24
36	39	59	47	53	6	13	20
34	58	38	42	46	52	7	14
57	33	35	37	41	45	51	8

Figure 2A.

I I I I I I	I I I I IO	OOI I IO	OI I I OI	I I I IOO	O I I IOO	OOI IOO	OOO OOO
OOO OO I	I IO I I I	I IO I IO	OOO I I O	OIO I OI	I I O IOO	OO I OOO	OOO I OO
I IO OOI	OOI OOI	I OI I I I	I O I I I O	I I I IOI	O IO OOO	IO I IOO	OIO IOO
I OO OIO	I I I OOI	O IO OOI	IOO I I I	O I I OOO	I I O IO I	OOI IO I	IOO IOO
OOO O I I	I OI OIO	OOO O IO	I OO OOO	O I I I I I	IOO I IO	I OI I OI	OOO I O I
I OO O I I	OOI O I I	I O I OOO	OOI O IO	O I I OOI	OIO I I I	O I I I IO	IOO IO I
I IO O II	I I O OOO	OIO OI I	I I O OIO	O IO O IO	IOO OOI	OOI I I I	OIO I IO
I I I OOO	I I I O I I	I OI O II	OI I OI I	I I I O IO	O I I O IO	I OI OOI	OOO I I I

Figure 2B.

Section "C" Second Reference Sequence

1	10	19	28	37	46	55	64
2	11	20	38	47	56	3	12
21	30	39	48	4	13	31	40
5	14	23	32	6	24	7	16
58	49	59	41	60	51	42	33
61	52	34	25	62	53	44	35
26	17	63	54	45	27	18	9
57	50	43	36	29	22	15	8

Figure 3A.

Area "A"	I I I I I I	I I O I I O	I O I I O I	I OO I OO	O I I O I I	O IO O IO	OO I OO I	OOO OOO
Area "B"	I I O I I I	I O I I I O	IOO IO I	O IO O I I	OO I O IO	OOO OO I	I O I I I I	I OO I I O
	O I I I O I	O IO I OO	OO I O I I	OOO O IO	I OO I I I	O I I I I O	OO I I OO	OOO O I I
	O I I I I I	O IO I I O	OO I I O I	OOO I OO	O IO I I I	OOO I O I	OO I I I I	OOO I I O
	I I O OOO	I I I OO I	I O I OOO	I I I O IO	I OO OOO	I O I OO I	I I O OIO	I I I O II
	O I I OOO	I OO OO I	I I O O I I	I I I I OO	O IO OOO	O I I OO I	I OO O IO	I O I O I I
	I I O I OO	I I I I O I	OO I OOO	O IO OOI	O I I O IO	I O I I OO	I I O I O I	I I I I I O
Area "C"	I I I OOO	I I O OOI	I O I O IO	IOO OI I	O I I IOO	O IO I O I	OOI I I O	OOO I I I

Figure 3B.

Example/Original Sequence

35 = IOI
OII
Includes
35, 48 and 59
Encompasses
44, 45 and 52
Intersects
36, 37, 43, 46,
47, 51, 53,54

1	2	3	4	5	6	7	8
9	10	11	12	13	14	15	16
17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48
49	50	51	52	53	54	55	56
57	58	59	60	61	62	63	64

I I I I I I	IIO II I	IOI I II	IOO I I I	OII I II	OIO I I I	OOI I I I	OOO I I I
I II IIO	IIO IIO	IOI IIO	IOO I IO	OII IIO	OIO I IO	OOI I IO	OOO I I O
I I I IOI	IIO IOI	IOI IOI	IOO IO I	OII IOI	OIO I OI	OOI I OI	OOO I O I
I I I IOO	I IO IOO	IO I IOO	IOO IOO	OI I IOO	OIO IOO	OOI IOO	OOO I OO
I I I O II	IIO OII	IOI OII	IOO OI I	OII OII	OIO OI I	OOI O II	OOO O I I
I I I OIO	I IO OIO	I OI OIO	IOO OIO	OI I OIO	OIO OIO	OOI OIO	OOO O IO
I I I OOI	I IO OOI	I OI OOI	IOO OOI	OI I OOI	OIO OOI	OOI OOI	OOO OO I
I I I OOO	I I O OOO	I O I OOO	I OO OOO	O I I OOO	O IO OOO	OO I OOO	OOO OOO

Primary Classification First Reference Sequence

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
1	1	1	31	29	25	21	15	9	1	25	15	5	25	13	31	17	1	17	31	13	25	5	15	25	1	9	15	21	25	29	31	32
	1	2	2	3	4	5	6	7	8	8	9	10	10	11	11	12	13	13	13	14	14	15	15	15	16	16	16	16	16	16	16	32
2	32	2	2	32	30	26	22	16	10	2	26	16	6	26	14	32	18	2	18	32	14	26	6	16	26	2	10	16	22	26	31	32
	31	1	2	2	3	4	5	6	7	8	8	9	10	10	11	11	12	13	13	13	14	14	15	15	15	16	16	16	16	16	32	16
3	2	31	3	3	1	31	27	23	17	11	3	27	17	7	27	15	1	19	3	19	1	15	27	7	17	27	3	11	17	30	27	30
	31	31	1	2	3	3	4	5	6	7	8	8	9	10	10	11	12	12	13	13	14	14	14	15	15	15	16	16	16	32	16	16
4	4	1	30	4	4	2	32	28	24	18	12	4	28	18	8	28	16	2	20	4	20	2	16	28	8	18	28	4	29	18	23	28
	30	31	31	1	2	3	3	4	5	6	7	8	8	9	10	10	11	12	12	13	13	14	14	14	15	15	15	16	32	16	16	16
5	8	3	32	29	5	5	3	1	29	25	19	13	5	29	19	9	29	17	3	21	5	21	3	17	29	9	19	28	5	12	19	24
	29	30	30	31	1	2	3	4	4	5	6	7	8	8	9	10	10	11	12	12	13	13	14	14	14	15	15	32	16	16	16	16
6	12	7	2	31	28	6	6	4	2	30	26	20	14	6	30	20	10	30	18	4	22	6	22	4	18	30	27	20	29	6	13	20
	28	29	30	30	31	1	2	3	4	4	5	6	7	8	8	9	10	10	11	12	12	13	13	14	14	14	32	15	15	16	16	16
7	18	11	6	1	30	27	7	7	5	3	31	27	21	15	7	31	21	11	31	19	5	23	7	23	5	26	31	10	21	30	7	14
	27	28	29	30	30	31	1	2	3	4	4	5	6	7	8	8	9	10	10	11	12	12	13	13	14	32	14	15	15	15	16	16
8	24	17	10	5	32	29	26	8	8	6	4	32	28	22	16	8	32	22	12	32	20	6	24	8	25	6	19	32	11	22	31	8
	26	27	28	29	29	30	31	1	2	3	4	4	5	6	7	8	8	9	10	10	11	12	12	13	32	14	14	14	15	15	15	16
9	32	23	16	9	4	31	28	25	9	9	7	5	1	29	23	17	9	1	23	13	1	21	7	24	9	24	7	20	1	12	23	32
	25	26	27	28	29	29	30	31	1	2	3	4	5	5	6	7	8	9	9	10	11	11	12	32	13	13	14	14	15	15	15	15
10	8	31	22	15	8	3	30	27	24	10	10	8	6	2	30	24	18	10	2	24	14	2	23	8	25	10	25	8	21	2	13	24
	25	25	26	27	28	29	29	30	31	1	2	3	4	5	5	6	7	8	9	9	10	11	32	12	12	13	13	14	14	15	15	15
11	18	7	30	21	14	7	2	29	26	23	11	11	9	7	3	31	25	19	11	3	25	22	3	22	9	26	11	26	9	22	3	14
	24	25	25	26	27	28	29	29	30	31	1	2	3	4	5	5	6	7	8	9	9	32	11	11	12	12	13	13	14	14	15	15
12	28	17	6	29	20	13	6	1	28	25	22	12	12	10	8	4	32	26	20	12	21	26	15	4	23	10	27	12	27	10	23	4
	23	24	25	25	26	27	28	29	29	30	31	1	2	3	4	5	5	6	7	8	32	9	10	11	11	12	12	13	13	14	14	15
13	8	27	16	5	28	19	12	5	32	27	24	21	13	13	11	9	5	1	27	20	13	4	27	16	5	24	11	28	13	28	11	24
	23	23	24	25	25	26	27	28	28	29	30	31	1	2	3	4	5	6	6	32	8	9	9	10	11	11	12	12	13	13	14	14
14	20	7	26	15	4	27	18	11	4	31	26	23	20	14	14	12	10	6	19	28	21	14	5	28	17	6	25	12	29	14	29	12
	22	23	23	24	25	25	26	27	28	28	29	30	31	1	2	3	4	5	32	6	7	8	9	9	10	11	11	12	12	13	13	14
15	2	19	6	25	14	3	26	17	10	3	30	25	22	19	15	15	13	18	7	2	29	22	15	6	29	18	7	26	13	30	15	30
	22	22	23	23	24	25	25	26	27	28	28	29	30	31	1	2	3	32	5	6	6	7	8	9	9	10	11	11	12	12	13	13
16	16	1	18	5	24	13	2	25	16	9	2	29	24	21	18	16	17	14	11	8	3	30	23	16	7	30	19	8	27	14	31	16
	21	22	22	23	23	24	25	25	26	27	28	28	29	30	31	1	32	3	4	5	6	6	7	8	9	9	10	11	11	12	12	13
17	32	15	32	17	4	23	12	1	24	15	8	1	28	23	20	16	17	16	15	12	9	4	31	24	17	8	31	20	9	28	15	32
	20	21	21	22	23	23	24	25	25	26	27	28	28	29	30	32	1	2	3	4	5	6	6	7	8	9	9	10	11	11	12	12
18	16	31	14	31	16	3	22	11	32	23	14	7	32	27	15	19	17	18	17	16	13	10	5	32	25	18	9	32	21	10	29	16
	20	20	21	21	22	23	23	24	24	25	26	27	27	28	32	30	31	1	2	3	4	5	6	6	7	8	9	9	10	11	11	12
19	2	15	30	13	30	15	2	21	10	31	22	13	6	14	26	22	18	16	19	18	17	14	11	6	1	26	19	10	1	22	11	30
	20	20	20	21	21	22	23	23	24	24	25	26	27	32	28	29	30	31	1	2	3	4	5	6	7	7	8	9	10	10	11	11
20	20	1	14	29	12	29	14	1	20	9	30	21	13	5	31	25	21	17	15	20	19	18	15	12	7	2	27	20	11	2	23	12
	19	20	20	20	21	21	22	23	23	24	24	25	32	27	27	28	29	30	31	1	2	3	4	5	6	7	7	8	9	10	10	11
21	8	19	32	13	28	11	28	13	32	19	8	12	20	12	4	30	24	20	16	14	21	20	19	16	13	8	3	28	21	12	3	24
	19	19	19	20	20	21	21	22	22	23	24	32	25	26	27	27	28	29	30	31	1	2	3	4	5	6	7	7	8	9	10	10
22	28	7	18	31	12	27	10	27	12	31	11	7	29	19	11	3	29	23	19	15	13	22	21	20	17	14	9	4	29	22	13	4
	18	19	19	19	20	20	21	21	22	22	32	24	24	25	26	27	27	28	29	30	31	1	2	3	4	5	6	7	7	8	9	10
23	18	27	6	17	30	11	26	9	26	10	30	18	6	28	18	10	2	28	22	18	14	12	23	22	21	18	15	10	5	30	23	14
	18	18	19	19	19	20	20	21	21	32	22	23	24	24	25	26	27	27	28	29	30	31	1	2	3	4	5	6	7	7	8	9
24	8	17	26	5	16	29	10	25	9	25	11	29	17	5	27	17	9	1	27	21	17	13	11	24	23	22	19	16	11	6	31	24
	18	18	18	19	19	19	20	20	32	21	22	22	23	24	24	25	26	27	27	28	29	30	31	1	2	3	4	5	6	7	7	8
25	32	7	16	25	4	15	28	8	24	8	24	10	28	16	4	26	16	8	32	26	20	16	12	10	25	24	23	20	17	12	7	32
	17	18	18	18	19	19	19	32	20	21	21	22	22	23	24	24	25	26	26	27	28	29	30	31	1	2	3	4	5	6	7	7
26	24	31	6	15	24	3	7	27	9	23	7	23	9	27	15	3	25	15	7	31	25	19	15	11	9	26	25	24	21	18	13	8
	17	17	18	18	18	19	32	19	20	20	21	21	22	22	23	24	24	25	26	26	27	28	29	30	31	1	2	3	4	5	6	7
27	18	23	30	5	14	6	2	14	26	8	22	6	22	8	26	14	2	24	14	6	30	24	18	14	10	8	27	26	25	22	19	14
	17	17	17	18	18	32	19	19	19	20	20	21	21	22	22	23	24	24	25	26	26	27	28	29	30	31	1	2	3	4	5	6
28	12	17	22	29	5	13	23	1	13	25	7	21	5	21	7	25	13	1	23	13	5	29	23	17	13	9	7	28	27	26	23	20
	17	17	17	17	32	18	18	19	19	19	20	20	21	21	22	22	23	24	24	25	26	26	27	28	29	30	31	1	2	3	4	5
29	8	11	16	4	28	4	12	22	32	12	24	6	20	4	20	6	24	12	32	22	12	4	28	22	16	12	8	6	29	28	27	24
	17	17	17	32	17	18	18	18	18	19	19	20	20	21	21	22	22	23	23	24	25	26	26	27	28	29	30	31	1	2	3	4
30	4	7	3	15	21	27	3	11	21	31	11	23	5	19	3	19	5	23	11	31	21	11	3	27	21	15	11	7	5	30	29	28
	17	17	32	17	17	17	18	18	18	18	19	19	20	20	21	21	22	22	23	23	24	25	26	26	27	28	29	30	31	1	2	3
31	2	2	6	10	14	20	26	2	10	20	30	10	22	4	18	2	18	4	22	10	30	20	10	2	26	20	14	10	6	4	31	30
	17	32	17	17	17	17	17	18	18	18	18	19	19	20	20	21	21	22	22	23	23	24	25	26	26	27	28	29	30	31	1	2
32	1	1	3	5	9	13	19	25	1	9	19	29	9	21	3	17	1	17	3	21	9	29	19	9	1	25	19	13	9	5	3	32
	32	17	17	17	17	17	17	17	18	18	18	18	19	19	20	20	21	21	22	22	23	23	24	25	26	26	27	28	29	30	31	1

The Sequencing of Pattern Display

A sequential listing is used to display an arrangement of the numerical values that can be assigned to the ten digits in the primary classification. Therefore a selection could be made from the 120 combinations of numerical values.

Values that are applied to each hand of the ten digits.

Line Number	Sequence Number				
1	1	2	4	8	16
2	1	2	4	16	8
3	1	2	8	4	16
4	1	2	8	16	4
5	1	2	16	4	8
6	1	2	16	8	4
7	1	4	2	8	16
8	1	4	2	16	8
9	1	4	8	2	16
10	1	4	8	16	2
11	1	4	16	2	8
12	1	4	16	8	2
13	1	8	2	4	16
14	1	8	2	16	4
15	1	8	4	2	16
16	1	8	4	16	2
17	1	8	16	2	4
18	1	8	16	4	2
19	1	16	2	4	8
20	1	16	2	8	4
21	1	16	4	2	8
22	1	16	4	8	2
23	1	16	8	2	4
24	1	16	8	4	2
25	2	1	4	8	16
26	2	1	4	16	8
27	2	1	8	4	16
28	2	1	8	16	4
29	2	1	16	4	8
30	2	1	16	8	4
31	2	4	1	8	16
32	2	4	1	16	8
33	2	4	8	1	16
34	2	4	8	16	1
35	2	4	16	1	8
36	2	4	16	8	1
37	2	8	1	4	16
38	2	8	1	16	4
39	2	8	4	1	16
40	2	8	4	16	1
41	2	8	16	1	4
42	2	8	16	4	1
43	2	16	1	4	8
44	2	16	1	8	4
45	2	16	4	1	8
46	2	16	4	8	1
47	2	16	8	1	4
48	2	16	8	4	1
49	4	1	2	8	16
50	4	1	2	16	8
51	4	1	8	2	16
52	4	1	8	16	2
53	4	1	16	2	8
54	4	1	16	8	2
55	4	2	1	8	16
56	4	2	1	16	8
57	4	2	8	1	16
58	4	2	8	16	1
59	4	2	16	1	8
60	4	2	16	8	1
61	4	8	1	2	16

62	4	8	1	16	2
63	4	8	2	1	16
64	4	8	2	16	1
65	4	8	16	1	2
66	4	8	16	2	1
67	4	16	1	2	8
68	4	16	1	8	2
69	4	16	2	1	8
70	4	16	2	8	1
71	4	16	8	1	2
72	4	16	8	2	1
73	8	1	2	4	16
74	8	1	2	16	4
75	8	1	4	2	16
76	8	1	4	16	2
77	8	1	16	2	4
78	8	1	16	4	2
79	8	2	1	4	16
80	8	2	1	16	4
81	8	2	4	1	16
82	8	2	4	16	1
83	8	2	16	1	4
84	8	2	16	4	1
85	8	4	1	2	16
86	8	4	1	16	2
87	8	4	2	1	16
88	8	4	2	16	1
89	8	4	16	1	2
90	8	4	16	2	1
91	8	16	1	2	4
92	8	16	1	4	2
93	8	16	2	1	4
94	8	16	2	4	1
95	8	16	4	1	2
96	8	16	4	2	1
97	16	1	2	4	8
98	16	1	2	8	4
99	16	1	4	2	8
100	16	1	4	8	2
101	16	1	8	2	4
102	16	1	8	4	2
103	16	2	1	4	8
104	16	2	1	8	4
105	16	2	4	1	8
106	16	2	4	8	1
107	16	2	8	1	4
108	16	2	8	4	1
109	16	4	1	2	8
110	16	4	1	8	2
111	16	4	2	1	8
112	16	4	2	8	1
113	16	4	8	1	2
114	16	4	8	2	1
115	16	8	1	2	4
116	16	8	1	4	2
117	16	8	2	1	4
118	16	8	2	4	1
119	16	8	4	1	2
120	16	8	4	2	1

LETTERS

Dear Sir,

I write in response to Frankie E. Franks' letter, published in the April 2001 issue.

Mr. Franks is quite correct in his assertion that there is nothing new about *Ridgeology*. Indeed the first pioneering research by Harris Hawthorne Wilder was published in the same year that Sir Edward Henry finished work on his classification system.

Ridgeology may well appear to be mumbo jumbo to Mr. Franks but, coming into fingerprints from a scientific background, I understand it perfectly.

Ridgeology is a scientific rationale to enable examiners to understand, explain and justify fingerprint identification. It is not just the use of pores and intrinsic ridge shapes to "supplement" a shortfall in the minutia count (minutia are still a very important part of the identification process, and always will be). *Ridgeology* will (and has to) "supplant" the dogma of the numeric threshold system.

Finally I would point out that it is the comparison of *Ridgeologists* with *Flat Earthists* that "defies logic". For the former base their decisions on scientific theory and research while the latter dogmatically refuse to recognize the established truth.

Yours sincerely,

David Fairhurst
Fingerprint Officer
Surrey Police

Dear Sir,

So, in truly Napoleonic fashion, Allan Bayle has anointed himself this country's leading ridgeologist (*Fingerprint Whorld*, Vol. 27 No. 104, April 2001). What a supreme act of arrogance. As an expert myself of more than 34 years experience, and one that has worked in fingerprint departments in more than 30 countries of the world, I would like to know upon just what Mr. Bayle bases his unassailable knowledge of ridgeology? Is it based upon the fact that he has taken all the courses and has given presentations on the subject? Or is it based upon the fact that he has examined thousands of cases in which ridgeology was the key and crucial aspect of the evidence? As far as I'm aware he has never given evidence of ridgeology in a British court, unlike myself, who did so two years ago, when a successful conviction was achieved. Unlike Mr. Bayle, I would not be so presumptuous to state that I was a leading expert in *any* aspect of fingerprint identification, although I do consider myself to have a considerable and varied knowledge of the subject… and more important, continue to practice day by day making identifications. Mr. Bayle's personal declaration is yet another example of the "super expert ethos", that is to say, "I can see things

that you can't," which sadly has played a vital role in those few controversial cases which have plagued British fingerprinting over recent years.

I would expect that many other able and conscientious fingerprint experts in the UK will feel equally irked by Mr. Bayle's presumptive title of being the UK's "leading ridgeologist". (If you say it enough times you start to believe it yourself). After all, what is a ridgeologist? I would argue, that *all* of us who are actively engaged in operational fingerprint duties are skilled in ridgeology and use it consciously or sub-consciously in *every* comparison that we make. Quite often, one of the very first things that we may look for on beginning a comparison may be those features which catch our eye but are not actual characteristics, e.g. creases, scars, ridge texture, enlarged pores, etc. I would argue that we have all been using such techniques for years and as such ridgeology is not new, merely an aspect of fingerprint identification wearing a new mantle.

I also take exception to Mr. Bayle's reference to *The Fingerprint Society*'s stand in relation to the McKie case. As a Founder and Honorary Life Fellow of the Society and its Secretary/ Assistant Editor for 15 years, I was never afraid to state my mind on matters relating to fingerprints and was involved in some controversies during that time. But as a fingerprint expert, I was also taught to be cautious. I am amazed that Mr. Bayle should be so bold, nay even reckless, as to accuse the four Scottish experts of incompetency. As far as I'm aware, none of the four experts in question has *yet* been found to be at fault or guilty of any error. Mr. Bayle's allegation of incompetency should have been expressed privately, not so publicly. Although Mr. Bayle has been involved in the enquiry officially, I do not see that it is up to him to express an opinion on the competency of *any* other officer.

In criticising the Committee for its lack of comment on the McKie issue, I think that Mr. Bayle has missed the point. The Committee, which consists of experienced and sensible working fingerprint officers, is fully aware of the consequences of commenting on the case, when the judicial procedure has not yet been completed. And as far as I'm aware, nobody outside of those who were directly involved in the case has seen the *original* material upon which the identification(s) was first made: it seems to me, that all the decisions made publicly by those persons not directly involved in the case have been made based upon copies of the marks which have appeared in newspapers and/or have been published on the Internet. It could certainly be regarded as foolhardy to come to concrete conclusions when one has not had the benefit of seeing the original material.

Furthermore, I think it is an affront to the reputation of Mr. Robert Mackenzie for Mr. Bayle to seek that officer's suspension, (presumably from the Committee and not from his professional post, although to which he alludes is not quite clear in Mr. Bayle's letter) as he too, as far as I'm aware, has not been found guilty of any error or malpractice.

In closing, I cannot agree with Mr. Bayle that the Committee's behaviour on the McKie matter is disgraceful. The matter is being dealt with via the correct and lawful channels and it is not for *The Fingerprint Society* to add anything further until the matter has been correctly resolved. After it has been resolved, yes, I would agree that then there should be an analysis of the whole affair, so that we can all learn from the unfortunate saga.

In closing, I would recommend that in future Mr. Bayle might wish to concentrate his efforts in the direction which he is, obviously, *so* greatly talented, ridgeology; why not aspire to be the *world*'s leading ridgeologist? However, in crowning himself the ridgeologist kingpin, he should remember what happened to Napoleon.

Martin Leadbetter FFS BA (Hons)
Hertfordshire,
Great Britain

THE FINGERPRINT SOCIETY

QUAERITE ET INVENIETIS
FOUNDED 1974

Patron: The Rt. Hon. The Earl Nelson of Trafalgar

AIMS OF THE SOCIETY: To advance the study and application of fingerprints and to facilitate co-operation among persons interested in this field of personal identification.
'FINGERPRINT WHORLD', a quarterly journal, is sent to all Members and Fellows, and is designed to extend interest in, and application of all matters appertaining to the fingerprint science.
Management of the Society is vested in a committee elected at each Annual General Meeting.

APPLICATION FOR MEMBERSHIP
(N.B. All applicants must be proposed by a paid-up Member/Fellow of the Society in good standing, or provide documentary support to assist consideration of application)
Please use **BLOCK LETTERS**

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WWW..... Email.....

Please specify current duties (eg Fingerprint Officer, SOCO, CHEM.TECH)

.....

I apply for Membership/Fellowship* of the Fingerprint Society and enclose payment as indicated below.
***NB.** Applicants for Fellowship **MUST** have at least **FIVE** years experience in fingerprint duties. Please also state **place and date** of attaining fingerprint expertise.[1]

.....

I certify that all the information supplied is true. I understand that this information will be held on computer[3] and will be used to compile a membership almanac which will be provided only to persons whose membership is current at publication date.[2]

Signature of Applicant..... Date .....

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Items of a scientific and technical content, professional opinion, reportage, work practices, case reports, historical essays, personal views, and any other subject matter that the Editor considers suitable, will be considered for publication in *Fingerprint Whorld*.

Papers of a scientific and technical content may include science and technology-based research papers involving chemistry, statistical analysis, advancements in fingerprint and scene of crime development techniques, computer enhancement and any other topics relating to research in and advancement of development techniques in connection with fingerprint and scene of crime-related disciplines. The primary aim of authors of such works will be to have novel experimental or interpretive content in their papers but equally acceptable will be works that give fresh perspectives on the history or progress of advancements to the present day, as these may benefit new students coming into their respective disciplines as sources of reference.

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Photographs and line art in original form but are acceptable on disk if saved as TIFF or EPS files.

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Fingerprint Whorld is a quarterly peer-reviewed journal that reflects the aims of *The Fingerprint Society*, which are to advance the study and application of fingerprints and to facilitate the cooperation among persons interested in this field of personal identification. It is devoted to the theory and practice of fingerprint identification science and its associated disciplines. To assist these aims *Fingerprint Whorld* recognises that its membership is international and multi-disciplinary and as such sees a need for both new and review articles across the spectrum of forensic science evidence gathering topics to assist in the continual professional development of all stages of the profession.

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