No. 126383

IN THE

SUPREME COURT OF ILLINOIS

PEOPLE OF THE STATE OF ILLINOIS, Plaintiff-Appellant, -vs- JOHN CLINE, Defendant-Appellee.	))))))))))	Appeal from the Appellate Court of Illinois, No. 1-17-2631. There on appeal from the Circuit Court of Cook County, Illinois , No. 15 CR 18158. Honorable Vincent M. Gaughan, Judge Presiding.

BRIEF AND ARGUMENT FOR DEFENDANT-APPELLEE

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ISSUE PRESENTED FOR REVIEW

When the State's sum total of evidence comes from a forensic latent print examiner who compares a partial print found at the crime scene to the defendant, but the State fails to present evidence that the examiner followed the established and accepted method in reaching his conclusion, does that evidence have any weight and is it insufficient to sustain a conviction?

STATEMENT OF FACTS

When Tom Slowinski came home to his apartment at 4057 North Kedvale on September 1, 2015, he found the door ajar, even though he had locked it on his way to work that morning. (R. 139-40). Inside, he found his apartment had been "ransacked" and some items were missing. (R. 141). After police arrived, Slowinski walked through his apartment with the responding officer to identify missing items, including his PlayStation 4, a laptop, his gun safe, a handgun, headphones, video games, and blu-ray discs. (R. 142-44). The headphones had been in a metal case, which Slowinski said had been moved from where he usually kept it. (R. 143-44).

Chicago Police evidence technician Hiram Gutierrez photographed Slowinski's apartment and lifted a partial print impression from the headphones case. (R. 149-51). He found no other prints or other forensic evidence. (R. 153).

Based on the partial print, police arrested John Cline on October 13, 2015. (R. 173, 180, 182). The State subsequently charged Cline with a single count of residential burglary. (Supp. C. 8-10). Cline ultimately opted for a bench trial, which began on December 14, 2016. (R. 135).

At trial, Slowinski said that he left his apartment, on the top floor of a three-storey walk-up, at 8:15 a.m. on September 1, 2015. (R. 139-40). When he got home at around 6:15 p.m. that night, he noticed scratches on the apartment's front door, which was ajar. (R. 140). Slowinski did not live with a roommate, and at the time of the burglary, had not given anyone else permission to access his apartment and did not know Cline. (R. 140-41, 144). Slowinski acknowledged that during

the previous week, he had been away, and had given his apartment key to a friend, John Heroff, in case of emergency. (R. 145). He had returned home over the weekend, and had gotten the key back from Heroff before the burglary occurred. (R. 147-48).

Slowinski testified he went inside and found the apartment was "kind of ransacked and torn apart." (R. 141). Things were thrown about, he said, and his possessions were scattered about. (R. 141). Slowinski did a preliminary sweep through the apartment and noticed his laptop and Playstation 4 were gone. (R. 141). At that point, he stepped into the hallway and called police. (R. 141-42). After officers responded, Slowinski went through his unit again and found more items had been taken, including his gun safe (with four firearms in it), video games, and movies. (R. 142).

At trial, Slowinski identified a photo of a headphones case in which he kept a pair of Shore headphones. (R. 143; St. Ex. No. 1). Slowinski said that when he returned home on September 1, 2015, the headphones were no longer in the case, and the case was sitting on top of a pile of clothes, which is not where he had left it. (R. 143-44). He pointed the case out to police. (R. 144)

Chicago Police Officer Hiram Gutierrez, a 16-year veteran evidence technician, testified he went to Slowinski's apartment the next day. (R. 149). Guiterrez said Slowinski pointed out some areas of the apartment that had been "disturbed," including the headphones case. (R. 150). Gutierrez dusted the case and found a latent print on it, which he lifted. (R. 151). He identified photos he took of Slowinski's apartment the morning after the burglary, as well as photos of the fingerprint impressions and the lift. (R. 150-52). He took no photos of the apartment's door.

(R. 150-153). Gutierrez said that he processed the rest of the scene and did not find any other latent prints or other forensic evidence. (R. 153). He acknowledged that the impression he had recovered was "not a full print." (R. 154).

Latent fingerprint analyst Daniel Dennewitz testified that he undertook an analysis of the fingerprint impression in this case. (R. 161-174). He explained that while he had been a police officer for fifteen years and worked at the Chicago Police Department's Latent Print Unit of its Record Division for eight years, he had only been analyzing, comparing, and searching latent fingerprints for "just over a year" at the time of trial. (R. 161). He said he received training from the FBI Criminal Justice Information Services Center, then did an apprenticeship with the Chicago Police Department. (R. 162).

Dennewitz said he reviewed the lift. (R. 169). On the lift, he found four latent prints, but only one was suitable for comparison. (R. 170). Dennewitz compared that partial fingerprint on the lift from the headphones case to a set of known prints from Cline. (R. 167-71). After mapping 20 points of comparison and marking nine of them on both prints, he concluded that the prints came from the same source, specifically the third finger on Cline's right hand. (R. 171-73).

Dennewitz acknowledged on cross-examination that the ideal fingerprint is complete, and that part of the print in question from the case was missing. (R. 174, 176). He repeated his opinion that the partial fingerprint on the case came from Cline. (R. 180).

Detective Timothy O'Brien interviewed Cline after his arrest. (R. 182). When asked about the address of 4057 North Kedvale, Cline said he "would not be over

in that area." (R. 184).

The State rested after O'Brien's testimony. (R. 185). Cline declined to testify and the defense presented no evidence. (R. 185-86).

In closing, the defense argued that a full third of the fingerprint was missing, and that there was no evidence beyond a reasonable doubt that the print was Cline's. (R. 187-88). Counsel also maintained that the State had not shown that Cline had not been at the apartment by someone's invitation, or that the print had not been left before the case was brought into the apartment. (R. 187-88).

The trial judge reviewed the evidence, and based on the partial fingerprint, found Cline guilty of residential burglary. (R. 189-91). The judge subsequently sentenced Cline to a prison term of eight years. (C. 116; R. 244). Cline has completed his sentence, but he still remains subject to his term of mandatory supervised release.[1]

On appeal, Cline contended the evidence was insufficient to convict him because: (1) The only evidence tying him to the burglary was the partial fingerprint found on the portable headphones case; and (2) Dennewitz's testimony regarding the print was incomplete because the State did not offer evidence Dennewitz properly followed the accepted methodology for identifying latent fingerprints. *People v. Cline*, 2020 IL App (1st) 172631, ¶ 14. The appellate court agreed and reversed Cline's conviction. *Id.* The court observed that the accepted methodology for latent print analysis is "ACE-V" – analysis, comparison, evaluation and verification.

[1] Illinois courts may take judicial notice of information appearing on the Illinois Department of Correction's website. *See People v. Ware*, 2014 IL App (1st) 120485, ¶ 29.

Id. at ¶ 18. Concluding that the State's evidence was insufficient to prove Cline guilty beyond a reasonable doubt, the appellate court stressed the State offered no evidence Dennewitz verified his conclusion that the print came from Cline. *Id.* at ¶¶ 18-21. Without evidence that Dennewitz's conclusion was verified, the State's case rested entirely on a "flawed examination of a single, incomplete fingerprint." *Id.* at ¶ 28. Thus, the court concluded the State failed to sustain its burden. *Id.*

Justice Walker specially concurred. *Id.* at ¶¶ 37-40 (Walker, J, specially concurring). Justice Walker maintained that the State's case also was insufficient to prove temporal proximity – that even if the print was Cline's, there was insufficient proof to establish he left it during the burglary on the portable headphones case. *Id.* (Walker, J., specially concurring). This Court granted the State's petition for leave to appeal on November 18, 2020.

ARGUMENT

Introduction

The entirety of the State's evidence against John Cline was from one partial latent fingerprint recovered from a headphones case, which a lone latent print examiner gave his opinion that it came from Cline's right middle finger. There was no evidence the analyst followed the proper latent print analysis method and verified his conclusion with another latent print examiner, no evidence Cline confessed to the crime, no evidence anyone saw Cline at the burgled apartment before, during, or after the burglary, and no evidence linking any stolen items from the apartment to Cline. From that one partial print impression, the State's theory of prosecution was that (1) Cline left the print; and (2) that he did so while burglarizing the complainant's apartment.

But "a society that values the good name and freedom of every individual should not condemn a man of a commission of a crime when there is reasonable doubt about his guilt." *In re Winship*, 397 U.S. 358, 365-65 (1970). Absent evidence the latent print examiner, Daniel Dennewitz, followed the proper latent print analysis methodology and had another latent print examiner verify his conclusion, and with no other evidence to establish that Cline was the burglar or left the print during the burglary, the evidence was so threadbare that, even viewing it in the light most favorable to the State, the State failed to establish Cline's guilty beyond a reasonable doubt. Consequently, where the evidence was insufficient to sustain a conviction, this Court should affirm the appellate court's reversal of Cline's conviction for residential burglary.

Standard of Review and Elements of the Offense

The standard of review for both Arguments I and II is well-established: When an appealing defendant challenges his conviction on the basis the evidence is insufficient, the reviewing court must look at the evidence, viewed in the light most favorable to the State, and determine if any rational trier of fact could have found the State proved the elements of the offense beyond a reasonable doubt. *Jackson v. Virginia*, 443 U.S. 307, 318-19 (1979); *People v. Murray*, 2019 IL 123289, ¶ 19. A criminal conviction will be reversed when the evidence is so unreasonable, improbable, or unsatisfactory as to justify a reasonable doubt of the defendant's guilt. *People v. Brown*, 2013 IL 114196, ¶ 48. Even on review, the State bears the burden of proving each element of the offense beyond a reasonable doubt. *Id.,* ¶ 52. The question is not whether there was any evidence to support the conviction, but rather if the factfinder's ultimate conclusion was a reasonable one, taking all rational inferences in the State's favor. *See Jackson*, 443 U.S. at 320 (Observing that any evidence could be a "mere modicum" of guilt, but that "it could not seriously be argued that such a 'modicum' of evidence could by itself rationally support a conviction beyond a reasonable doubt."); *Murray*, 2019 IL 123289, ¶ 19. While a factfinder's determination is entitled to great deference, it is not conclusive and binding upon this Court. *Murray*, 2019 IL 123289, ¶ 19; *People v. Smith*, 185 Ill. 2d 532, 542 (1999).

A person commits residential burglary when they knowingly and without authority enter or remain in the dwelling of another with the intent to commit a felony there. 720 ILCS 5/19-3(a) (West 2015). The State has properly identified

it must prove two distinct propositions: 1) the *corpus delicti*, or that a burglary occurred; and 2) that the defendant committed it. (St. Br. 9). Cline concurs with the State that, based on Slowinski's testimony, the State proved the *corpus delicti* of the case: that a burglary occurred. As the appellate court correctly recognized, and as detailed below, the State did not sufficiently prove beyond a reasonable doubt that Cline was responsible for the burglary.

I.

Absent evidence that another latent print examiner verified Dennewitz's conclusion the recovered partial print matched a sample from Cline, Dennewitz's failure to follow the established method in the very science in which he sought to render an "expert" opinion means there is no weight to his conclusion and it is insufficient to prove Cline left the print.

For more than 100 years, Illinois courts have embraced verified fingerprint identification evidence. *See People v. Jennings*, 252 Ill. 534, 546-47 (1911) (four expert witnesses testified regarding fingerprint evidence, verifying each other's conclusion that prints left on the scene matched the plaintiff-in-error). Even at the onset, fingerprint evidence was admissible because this Court in *Jennings* was "disposed to hold from the evidence of the four witnesses who testified, and from the writings we have referred to on this subject, that there is a scientific basis for the system of finger print identification, and that the courts are justified in admitting this class of evidence; that this method of identification is in such general and common use that the courts cannot refuse to take judicial cognizance of it." *Id.* at 549.

Thus, the first time this evidence appeared in Illinois courts, this Court approved fingerprint evidence when it was *verified*. That has not changed in the

109 years since *Jennings*. Today, expert testimony on the topic of latent print continues to be used in Illinois courtrooms. *See People v. Luna*, 2013 IL App (1st) 072253, ¶¶ 68-81.

The universally-accepted methodology as the minimally reliable method to match a known print to a latent one – Analysis, Comparison, Evaluation, and Verification, or ACE-V – is just as well-established in Illinois law. *Luna*, 2013 IL App (1st), ¶¶ 61-84; *see also People v. Negron*, 2012 IL App (1st) 110194, ¶ 37; *People v. Mitchell*, 2011 IL App (1st) 083143, ¶ 99 (Gordon, J., dissenting); *see also* Scientific Working Group on Friction Ridge Analysis, Study and Technology *Document #10, Standards for Examining Friction Ridge Impressions and Resulting Conclusions (Latent / Tenprint)* (Mar. 2013) (hereafter "NIST").[2] In fact, between this Court's decision in *Jennings* and now, the procedure behind fingerprint (now called latent print or friction ridge) analysis has changed very little. *See Luna*, 2013 IL App (1st) 072253, ¶ 61. ("While the steps performed under ACE–V are essentially the same steps performed by fingerprint experts over the last hundred years, ACE–V has been identified in forensic literature as a means of comparative analysis of evidence since 1959.")

Adherence to the ACE-V methodology is important to understand why the State's case here was insufficient to prove Cline's guilt. Without proof that

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[2]Accessible at: https://www.nist.gov/document/swgfastexaminations-conclusions20130427pdf (last accessed October 12, 2021). The authoring organization has since been consolidated into the U.S. Department of Commerce's National Institute of Standards and Technology, which hosts the document. *See* http://clpex.com/swgfast/ (last accessed on October 12, 2021).

Dennewitz's conclusion was verified by another examiner, the State failed to prove Dennewitz followed the accepted analytical method for fingerprint identification. By missing a key step in the process, Dennewitz's conclusion cannot be afforded any weight, and with no other evidence establishing Cline was the burglar, the State's evidence was insufficient to prove his guilt beyond a reasonable doubt.

A. The ACE-V method requires that when an examiner if of the opinion that a latent print is the same as a known sample – known as individualization – their conclusion must be verified.

The Federal Bureau of Investigation ("FBI") Laboratory mandates that its examiners use the ACE-V method to make conclusions. L. Haber and R.N. Haber, *Scientific validation of fingerprint evidence under* Daubert*,* 7 Law, Probability and Risk 2 (June 2008); *see also U.S. v. Havvard*, 117 F. Supp. 2d 848, 853 (S.D. Ind. 2000) (FBI fingerprint expert testified that all positive identification opinions must be verified by a second qualified expert). This is something Dennewitz would have known as he testified that he took classes taught by the FBI. (R. 162).

The ACE-V process involves four distinct steps. *Luna*, 2013 IL App (1st) 072253, ¶ 61. First, the examiner will **analyze** the unknown latent print to ascertain its quality and suitability for comparison. *Id.; see also* NIST, *Doc. 10,* § 5.1 If in the examiner's opinion the print has sufficient detail, they begin a comparison to a known print. *Luna*, 2013 IL App (1st) 072253, ¶ 61. The **comparison** process is visually measuring and comparing details between the latent and known print impressions that the examiner believe correspond with each other. *Id.* This can include a laundry-list of different details, such as ridge flows, ridge counts, the shape of the core, and other factors. *Id.* The clarity of the two impressions greatly

affects the amount of detail an examiner can compare. *Id.*; *see also* NIST, *Doc. 10,* § 5.2.

After making an analysis and comparison, the examiner will make an **evaluation** and come to an opinion if the recovered latent print is from a different source (known as "exclusion") or from the same source (an "individualization") as the known impression. NIST, *Doc. 10,* § 5.3.2. This process depends almost entirely upon the examiner; since the ACE-V method does not specify particular measurements or a standard test method, examiners must make subjective assessments throughout it. National Research Council of the National Academies, *Strengthening Forensic Science in the United States: A Path Forward* 139 (2009) (hereafter "NRC Report").[3] Thus, "subjectivity is intrinsic to friction ridge analysis[.]" *Id*.

After an examiner arrives at a conclusion, that conclusion is **verified** when another qualified examiner repeats the steps and observations above. *Luna*, 2013 IL App (1st) 072253, ¶ 61; NIST, *Doc. 10* § 5.4. The subsequent examiner uses the same ACE process to support or refute the conclusions of the original examiner. *Luna*, 2013 IL App (1st) 072253, ¶ 61; NIST, *Doc. 10* § 5.4. Verification is considered integral to latent fingerprint identification as it is one of the four necessary steps in the full method. *See Luna*, 2013 IL App (1st) 072253; NIST, *Doc. 10* § 5.4 ("All other conclusions resulting from the evaluation phase should be verified.").[4]

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[3] Available at https://www.ojp.gov/pdffiles1/nij/grants/228091.pdf (last accessed October 12, 2021).

[4] Completion of the verification step does not guarantee infallibility, however, as itself has been criticized for not being "rigorously shown to have the

In the parlance of the field, Dennewitz's conclusion was an "individualization:" he was of the opinion that the latent print found on the scene was individualized to Cline's. An "individualization" occurs when the examiner determines that there are sufficient features in agreement to determine that the impressions came from the same source. NIST, *Doc. 10* at § 5.3.2.2. A conclusion of individualization "*shall* be verified. All other conclusions resulting from the evaluation phase should be verified." *Id.* at § 5.4.2 (emphasis added). Thus, any individualization must be verified by a separate examiner, pursuant to the established ACE-V method, in order to fully and properly complete the ACE-V method.

B. This Court should take judicial notice that the ACE-V methodology is the accepted method by which to analyze latent prints.

This Court can and should look to learned treatises from reputable sources to understand latent print analysis. This Court did just that a century ago in *Jennings*, and it should do so again here. 252 Ill. at 549.

The State takes umbrage that the appellate court considered these "extra-record materials" to analyze Dennewitz's testimony. (St. Br. 13-14). The State's position is without support and ignores that this Court and other Illinois courts

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capacity to consistently and accurately demonstrate a connection between evidence and a specific individual or source." NRC Report, at 7; *see generally* Simon A. Cole, *Grandfathering Evidence: Fingerprint Admissibility Rulings from* Jennings *to* Llera Plaza *and Back Again*, 41 Am. Crim. L. Rev. 1189 (2004); Robert Epstein, *Fingerprints Meet* Daubert*: the Myth of Fingerprint "Science" Revealed*, 75 S. Cal. L. Rev. 605 (2002); Tamara F. Lawson, *Can Fingerprints Lie?: Re-Weighing Fingerprint Evidence in Criminal Jury Trials*, 31 Am. J. Crim. L. 1 (2003); Sandy L. Zabell, *Fingerprint Evidence*, 13 J.L. & Pol'y 143 (2005).

routinely take judicial notice of various scientific principles and authoritative treatises that are generally known and accepted, or of facts which, while not generally known, are readily verifiable from sources of indisputable accuracy. *See, e.g.*, *Murdy v. Edgar*, 103 Ill. 2d 384, 394 (1984); *People v. Davis*, 65 Ill. 2d 157, 161 (1976); *People v. Lee*, 256 Ill. App. 3d 856, 863 (1st Dist. 1993); *see also Theofanis v. Sarrafi*, 339 Ill. App. 3d 460, 471 (1st Dist. 2003) (reviewing court took judicial notice of laws of mathematics and computational methods scientists generally accept as irrefutable to analyze evidence in the case).

For instance, in *People v. McKown*, this Court looked at a myriad of scientific articles submitted by the State and the defendant as it considered the State's argument that it should take judicial notice that HGN testing was a reliable method to determine impairment from alcohol consumption. 226 Ill. 2d 245, 272-75 (2007). In support of its argument, the State relied on this Court's decision in *In re Commitment of Simons*, which established that a court reviewing a trial court's *Frye* analysis may consider not only the record, but also "sources outside the record, including legal and scientific articles, as well as court opinions from other jurisdictions." *McKown*, 226 Ill. 2d at 272 (quoting *In re Commitment of Simons*, 213 Ill. 2d 523, 531 (2004)). Ultimately, this Court declined to take judicial notice on the basis that the submitted articles showed that there were varying opinions on the question in the scientific literature instead of "the unequivocal or undisputed viewpoint necessary for us to take judicial notice." *Id.* at 275. Of course, in this case, there are no varying opinions that ACE-V is universally-accepted as the minimally reliable method by which to analyze latent print impressions. *Luna*,

2013 IL App (1st) 072253, ¶¶ 68; L. Haber and R.N. Haber, *Scientific validation of fingerprint evidence under* Daubert, 7 Law, Probability and Risk 2 (June 2008).

Likewise, in *People v. Garrett*, this Court had to determine if gunshot wound evidence supported a murder conviction. 62 Ill. 2d 151, 163 (1975). In analyzing the evidence, both parties referred to "a number of treatises" in support of their arguments. *Id.* at 165. This Court found it could "appropriately" consider these treatises that they agreed "the characteristics of an entry wound will vary with the distance from which a weapon is fired." *Id.*; *see also Miller v. Alabama*, 567 U.S. 460, 471-73, 472 n.5 (2012) (detailing the science and social science studies relied upon by the Court in *Roper v. Simmons*, 543 U.S. 551, 570 (2005), and *Graham v. Florida*, 560 U.S. 48, 68 (2010), and its continued reliance on such studies when holding that children are constitutionally different than adults).

More specifically to this case, in *People v. Wilhoite*, the appellate court had to consider whether the defendant had proved by a preponderance of evidence that she was not sane at the time of the offense. 228 Ill. App. 3d 12, 19 (1st Dist. 1991). The State objected to the court's reliance on the Diagnostic and Statistical Manual of Mental Disorders, third edition revised ("DSM-III-R"), as it was not admitted as substantive evidence and not part of the record. *Id.* at 22. The court rejected that argument as the parties and expert witnesses at trial relied upon the DSM-III-R during their testimony. *Id.* The court also recognized that the DSM-III-R was the diagnostic manual drafted by the American Psychiatric Association for detailing diagnostic classifications used in the mental health field and held it could consider scholarly authority referred to by the parties in interpreting the

evidence. *Id.* at 23 (citing generally to *Garrett*). After discussing the relevant portions of the DSM-III-R in depth, the court found that the State's expert's opinion should be given no weight and concluded that the defendant was not guilty by reason of insanity. *Id.* at 24-28.

Accordingly, the State is wrong when it asserts that the appellate court improperly relied on extra-record materials. (St. Br. 13-14). To the extent the State implies the prior judicial decision of *Luna* that discussed the ACE-V method in detail was an "extra-record material" (St. Br. 13), it offers no authority for the proposition that a reviewing court is prevented from considering and relying upon well reasoned and detailed published precedents on similar legal or factual issues. Nor could it as such a position contravenes the entire premise of the American common law legal system.

In this case, the appellate court appropriately began by looking at a comprehensive discussion of latent print analysis and the "ACE-V" method from *Luna*, which cited to this Court's decision in *McKown*. *Luna*, 2013 IL App (1st) 072253, §§ 65, 70, 80. The *Luna* court's discussion of the method and its general acceptance aided the *Cline* court in understanding the evidence in this case and the reasonableness of the trial court's conclusion derived from it. *Cline*, 2020 IL App (1st) 172631, ¶¶ 18-19. The appellate court then appropriately looked at scientific articles that further discussed the ACE-V method and the importance of the final verification process in that method. *Id.* at ¶¶ 19-21.

What the appellate court did here was no different than what this Court did in *Garrett* and *Wilhoite*: use scholarly authority to understand a universally-

accepted scientific methodology and interpret particular evidence with it. Referring to these sources is hardly conducting some sort of "private investigation" as the State suggests. (St. Br. 14).

In addition to *Luna*, Illinois courts have consistently determined that verification is a standard step in the identification process. *See, e.g.*, *Negron*, 2012 IL App (1st) 101194, ¶21 ("[The fingerprint expert's] opinion was independently reviewed and verified by latent fingerprint examiner Fred Scott"); *Mitchell*, 2011 IL App (1st) 083143, ¶84 ("[The fingerprint expert's] conclusion was then verified by another examiner"); *People v. Safford*, 392 Ill. App. 3d 212, 220 (1st Dist. 2009) ("each of his print identifications was verified by another examiner"); *People v. Yancy*, 368 Ill. App. 3d 381, 383 (1st Dist. 2005) ("[The fingerprint expert] further testified that the quality assurance department randomly reidentified the prints and agreed with her conclusion"); *People v. Prince*, 362 Ill. App. 3d 762, 776 (1st Dist. 2005) ("latent fingerprint examiner Deborah McGarry [testified] that her work is peer reviewed and verified by another researcher").

In sum, it is entirely appropriate for this Court to take judicial notice of the ACE-V method as the standard procedure friction ridge analysts should follow, even in a sufficiency analysis. *See Luna*, 2013 IL App (1st) 072253, ¶ 68 (listing cases from a dozen jurisdictions, both state and federal, accepting the ACE-V method.)

C. Because the State offered no evidence Dennewitz completed the ACE-V method and had his individualization verified, his conclusion cannot be afforded any weight.

The crux of this case is this: what if the State offers no evidence a latent

print analyst's conclusion was verified by another? Here, Dennewitz testified the partial latent print found on the scene and a known print from Cline "came from the same source." (R. 173). But the State offered *no* evidence anyone else verified Dennewitz's conclusion or that Dennewitz asked someone else to verify his findings. Thus, the evidence here is missing the final step in the ACE-V analytical process – verification.

This missing evidence does not make Dennewitz's testimony inadmissible, as the State seems to suggest Cline wants this case to be about. (St. Br. Arg. II-B-1-a). Rather, "an expert's *application* of generally accepted techniques go to the weight of the evidence, rather than its admissibility." *Donaldson v. Central Illinois Public Service Co.*, 199 Ill. 2d 63, 81 (2002) (emphasis in original), *abrogated on other grounds by In re confinement of Simons*, 213 Ill. 2d 523 (2004); *Luna*, 2013 IL App (1st) 072253, ¶ 70; *see also People v. Hickey*, 178 Ill. 2d 256, 279-80 (1997) (holding that whether work performed by DNA analyst followed proper methodology goes to weight of evidence); *People v. Johnson*, 318 Ill. App. 3d 281, 287 (1st Dist. 2000) (holding that issues concerning the quality of testing process itself, such as laboratory method and the manner in which it was followed, is a matter that goes to the weight of the evidence).

However, since the State offered no evidence Dennewitz followed the standard ACE-V method, his testimony cannot be afforded any weight. This is consistent with the law and literature on latent print analysis, which emphasizes time and again that verification is a critical and necessary step. *Luna*, 2013 IL App (1st) 072253, ¶ 61; *U.S. v. Rose*, 672 F. Supp. 2d 723, 726 (D. Md. 2009) (noting that

an FBI Inspector General's review of an infamous misidentification "teaches the importance of independent verification of an examiner's findings[.]"); *see also Wilhoite*, 228 Ill. App. 3d at 25 (holding that the opinion of a psychiatric doctor that was inconsistent with the widely-accepted diagnostic manual "raised serious doubts as to the validity of [his] conclusion and thus was entitled to 'little if any' weight.") (quoting *People v. Palmer*, 139 Ill. App. 3d 966, 973 (2d Dist. 1985)).

As a latent print examiner, Dennewitz was trained at the FBI Criminal Justice Information Services Center. (R. 162). Thus, the FBI standards and his lack of adherence to the accepted methodology must result in his conclusion being disregarded. If an unverified conclusion is not good enough for the FBI, it should not be enough to find a man guilty. *See Latent Prints: A Perspective on the State of the Science*, 11 Forensic Sci. Commc'n No. 4 (2009).[5] In short, Dennewitz's opinion cannot be "within a reasonable degree of scientific certainty based on [his] experience, training, and education" when no evidence shows he actually adhered to the correct science by following his training and using the proper and accepted scientific method. (R. 173).

This is particularly true considering the nature of the evidence of latent print analysis. As detailed above, fingerprint analysis is a highly-subjective field, and the "outcome of a friction ridge analysis is not necessarily repeatable from examiner to examiner." NRC Report at 139. Two examiners may look at the same

[5] Available at: https://archives.fbi.gov/archives/about-us/lab/forensic-science-communications/fsc/oct2009/review/2009_10_review01.htm#Recommendations (last visited October 12, 2021).

prints and come to different conclusions, and "human factors can affect the outcome" of the analysis. National Institution of Standards and Technology Report of the Expert Working Group on Human Factors in Latent Print Analysis, *Latent Print Examination and Human Factors: Improving the Practice through a Systems Approach* 8 (Feb. 17, 2012)[6].

It follows, then, that forensic examiners must follow proper procedures if the evidence they offer is to have any weight. Here, drug cases provide a useful analogy. In *People v. Jones*, the defendant was charged with possession of five separate packets of a rocky white substance police believed was narcotics. 174 Ill. 2d 427, 428 (1996). Combined, the five packets weighed 1.4 grams. *Id.* The State selected two of the packets and tested their contents, but did not test the other three. *Id.* The two tested packets showed the presence of cocaine. *Id.* Based on the weight of all five packets, the State charged Jones with possession with intent to deliver 1.4 grams of cocaine, a Class 1 felony. *Id.* The appellate court reversed, finding the evidence only supported a finding that the defendant possessed 0.59 grams – the combined weight of the two tested packets – and reduced the conviction to a Class 2 felony. *Id.*

This Court affirmed. *Jones*, 174 Ill. 2d at 430. In doing so, this Court focused on the procedure the State's chemist followed and observed that when an expert omits a step in the analytical process, no inference can be drawn due to the omitted step. *Id.* Absent that extra step, the evidence was insufficient to sustain the

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[6] Available at: https://www.nist.gov/publications/latent-print-examination-and-human-factors-improving-practice-through-systems-approach (last accessed October 12, 2021).

conviction of the untested packets. *Id.*

Jones demonstrates two things. First, procedure matters: when the State's evidence skips a step in the analytical process, it leaves a gap that only conjecture and speculation can fill. The State cannot omit a step in testing evidence then hope a reviewing court will look past its flawed procedure. Without testing each packet, it was impossible to know what actually was in the other three packets. Thus, the weight of the State's evidence did not measure up – literally or figuratively.

Second, that the analyst did not follow proper procedures was not a question about the admissibility of the evidence, but rather its sufficiency and thus the weight it should be given. The fact that the State tested only two of the packets in *Jones* did not render that testimony inadmissible, it instead went to the State's evidence as a whole. So when the State omits a key step in the analytical process, that omission is a substantive failing and affects the sufficiency of the State's evidence presented at trial. This harmonizes with the principle espoused by this Court in *Donaldson* that an expert's application of a generally-accepted technique goes to the weight of that evidence, not whether it is admissible or not. 199 Ill. 2d at 81. When the State fails to provide proof that proper methodology was followed, that is tantamount to a failure of proof of the conclusion as a whole.

Here, without proof of independent verification of Dennewitz's opinion, we are missing a key step in the ACE-V methodology, and the State has offered an incomplete analysis, just as it did in *Jones*. Since we are missing that last step, Dennewitz's conclusion cannot and should not be afforded any weight. In other words, by skipping evidence that someone verified Dennewitz's opinion, the State

has made the same mistake it did in failing to test the other three drug packets. It did not get a pass in *Jones*, and it should not here. Since there is no evidence Dennewitz or the State completed the verification in the ACE-V method, any conclusion derived from the incomplete "ACE" cannot be afforded any weight and is insufficient to prove the recovered partial print match's Cline's print. Since Dennewitz's conclusion cannot be afforded any weight, it is insufficient to prove Cline guilty of residential burglary.

Overall, the State seeks to distract this Court from the issue at hand as it tries to turn this argument into one about admissibility, not sufficiency. (St. Br. Sr. II-B-1). The current state of Illinois law allows the admission of fingerprint evidence, and Cline does not contend otherwise. Cline does argue, however, that Dennewitz's conclusion, absent verification and proof that proper procedure was followed, cannot satisfy the State's burden to prove Cline was the burglar.

The State also tries to shift the burden to Cline when it contends he should have exposed any inadequacies in Dennewitz's methodology "through cross-examination." (St. Br. 15). This Court has already recently rejected a nearly identical argument. *See Murray*, 2019 IL 123289, ¶¶ 29-30. It should do so again in this case.

In *Murray*, the defendant contended the State's gang expert did not disclose specific crime evidence to prove the Latin Kings were a "street gang" as defined by statute. *Id.*, ¶ 17. The State contended that once its expert opined the Latin Kings were a street gang, the burden shifted to the defendant to challenge that opinion. *Id.*, ¶ 27. This Court observed that this shifted the burden of proof, since

the State's expert opinion, on its own, was insufficient to establish the elements of the offense. *Id*. Accepting the State's argument would have meant the defendant would have to disprove the State's case before the State had established the elements of the crime. *Id*.

Important here, this Court recognized the purpose of cross-examination is to highlight less obvious flaws in the State's case and not to act as an alternative way the State can establish the elements of an offense:

> In general, the purpose of cross-examination is to highlight the flaws and omissions in the evidence presented during direct examination. As a practical matter, cross-examination is necessary only where the flaws and omissions are not readily apparent from the previous testimony on direct examination. In a criminal case, *cross-examination* of the State's witnesses *is not intended* to serve as *an alternative means of establishing the elements of the offense beyond a reasonable doubt*.

Murray, 2019 IL 123289, ¶ 30 (citing *People v. Mosby*, 25 Ill. 2d 400, 403 (1962)) (internal citation omitted) (emphasis added).

In other words, if the State fails to present particular evidence, it is not incumbent upon the defendant to cross-examine the State's witnesses about that failure. "Because the State bears the burden of proof, it similarly bears the consequences of any omission of proof." *Id.*; *see also People v. Powell*, 2021 IL App (1st) 181745, ¶ 49 ("Assuming [the State's identification witness] had the requisite knowledge to sustain a conviction, the State controls the questions it asks its witnesses and knows the legal elements it must prove to secure a constitutional conviction, and the State bore the burden to draw that knowledge out. It failed to do so."). As in *Murray*, the State tries here to escape the consequences of its failure to present its evidence at trial by claiming it was Cline's burden to clarify

the State's missing evidence through cross-examination. (St. Br. 15). This Court has already rejected such arguments in *Murray* and should reject this argument out of hand.

Moreover, the State's contention that perhaps Cline did not ask Dennewitz if he verified his conclusion was because he would have testified he did, is pure speculation and this Court should pay it no heed. (St. Br. 15-16). It also does not matter what Cline did or did not ask Dennewitz when considering if the State's evidence is sufficient. The prosecution is entitled to prove its case by whatever evidence it chooses, so long as its does not run afoul of the rules of evidence. *See, e.g.*, *Old Chief v. U.S.*, 519 U.S. 172, 186-87 (1997); *People v. Walker*, 211 Ill. 2d 317, 338-39 (2004) (holding that the State cannot prove a defendant's felon status by entering the record of conviction when a stipulation to the defendant's status is equally probative of the element in question and does not create a substantial risk of prejudice). In other words, the State gets to pick how to present its case; it cannot now try to hide from the consequences of those decisions if it missed something.

And the State's contention that it could not have presented the verification testimony because the rules of evidence foreclosed it from doing so similarly holds no water. (St. Br. 16) For example, the State could have asked Dennewitz: "Did you submit your findings to another latent expert for verification?" That question does not call for hearsay, only what Dennewitz's personally did. The State could then have called the verifying expert, who would have testified as to his independent conclusion. Notably, the State has had no problem admitting testimony from a

verifying expert in other fingerprint cases. *See, e.g.*, *People v. Parker*, 2019 IL App (3d) 160455, ¶¶ 18-20 (State called both initial latent examining expert and verifying examiner at trial; *Negron*, 2012 IL App (1st) 101194, ¶ 23 (evidence testifying fingerprint examiner's results were verified independently by another latent print examiner admitted at trial); *People v. Safford*, 392 Ill. App. 3d 212, 220 (1st Dist. 2009) (testifying fingerprint examiner testified his conclusions were verified by another examiner).

In summary, absent proof Dennewitz complied with the appropriate analytical method and verified his conclusion, his opinion carries no weight. His conclusion cannot sustain the State's burden and prove Cline was the burglar. And as discussed next, there is no other evidence supporting even a speculative inference – much less a reasonable one – that Cline burglarized the apartment.

D. No other evidence supports a reasonable inference Cline was the burglar.

The only piece of evidence that suggested Cline was responsible for the burglary was Dennewitz's opinion that the partial print found on the headphones case was created by Cline. (R. 173). As this opinion is not worthy of any weight, Cline's conviction must be reversed as the State presented no other evidence at trial. After all, evidence can only be looked at the light most favorable to the State if there is actual evidence to consider. *See Jackson v. Virginia*, 443 U.S. 307, 318-19 (1979); *People v. Murray*, 2019 IL 123289, ¶ 19. Here there is no other evidence to support the State's theory that Cline was the person who entered Slowinski's apartment and burglarized it.

No other ridge impressions were lifted from the apartment and no other

forensic evidence was collected. (R. 153). Slowinski testified that he did not see who had broken into his apartment. (R. 139-41). He had given a key to his apartment to a friend the week before, but had received it back before the burglary. (R. 145, 147). After the police arrested Cline, he was questioned and told the police that he was not in the area of the apartment. (R. 184). The State also did not present any evidence that items taken from the apartment were found in Cline's possession or that Cline was seen in the area of the apartment around the time of the burglary. (R. 139-85).

If the State had *any* supporting evidence – a verification from another fingerprint examiner, evidence another print was found and matched to Cline, that Cline was in possession of any of the stolen items, or testimony from someone who saw Cline outside Slowinski's apartment – the trial court's ultimate conclusion arguably could be based on reasonable inferences and not conjecture and speculation. That is not the situation in this case and the trial court may not draw unreasonable inferences from no facts to ultimate conclusions. *Jackson*, 443 U.S. at 319. Absent any other supporting evidence that is what the trial court has done here, and why the State's case is insufficient.

***

In sum, the entirety of the State's trial evidence against Cline came from Dennewitz. Critically, the State failed to demonstrate that the proper latent print method was followed. Taken in the light most favorable to the State, its evidence was insufficient because it requires any rational factfinder to resort to speculation rather than reasonable inferences. This Court should affirm the finding of the

appellate court and conclude that Cline's residential burglary conviction cannot stand.

II.

The State's evidence failed to satisfy the temporal proximity criteria, proving beyond a reasonable doubt that Cline left the print during the burglary.

Even if Dennewitz's insufficient testimony was proof beyond a reasonable doubt that the print on the case was Cline's – something Cline does not concede – the State offered *no* evidence that Cline left the partial print during the burglary. As the special concurrence below observed, Cline's fingerprint "was found only on a headphone case and nowhere else in the apartment." *Cline*, 2020 IL App (1st) 172631, ¶ 39 (Walker, J., specially concurring). Coupled with the fact the headphone case was an easily-portable object, looking at the evidence in the light most favorable to the State, the State failed to prove beyond a reasonable doubt Cline left the print during the burglary.

To sustain a conviction based solely on fingerprint evidence, fingerprints corresponding to those of the defendant must have been found in the vicinity of the crime and under circumstances establishing beyond a reasonable doubt that the fingerprint was made at the time of the offense. *People v. Rhodes*, 85 Ill. 2d 241, 249 (1981). The latter element is known as "temporal proximity criteria" – in other words, proof the defendant left the print when committing the crime. *See, e.g.*, *People v. Gomez*, 215 Ill. App. 3d 208, 216-17, 219 (2d Dist. 1991) (reversing conviction for first degree murder due to State not establishing that defendant's fingerprint was left at the time of the offense). Even viewed in a deferential light,

the State's evidence in the current case cannot establish beyond a reasonable doubt that, assuming it is his print, Cline left it during the burglary.

A pair of federal cases illustrate why and are highly instructive. *Travillion v. Superintendent Rockview SCI,* 982 F.3d 896 (3d Cir. 2020); *Mikes v. Borg*, 947 F.2d 353 (9th Cir. 1991). In *Travillion*, the defendant was charged with robbing a store; in the process, he left behind at the scene a manilla folder with some papers he had been carrying. 982 F.3d at 898. Police later found two thumb prints, a left ring finger print, and a left middle finger print on the manilla folder, and a left thumb print on the papers in the folder. *Id.* at 899. The police submitted the prints for comparison and it was determined they matched the defendant. *Id.* The defendant was convicted of robbery almost entirely on this match. *Id.* at 900.

The Third Circuit Court of Appeals, reviewing the defendant's habeas denial and the state court's interpretation of the *Jackson* standard, found the evidence unsatisfactory. *Id.* at 904-05.[7] In doing so, the court observed that the defendant's fingerprints were "only found on easily moveable objects" and "there was no evidence of his prints anywhere else at the crime scene." *Id.* at 904. Moreover, the State offered no other evidence as to the age of the prints or how long the prints could remain on the manilla folder. *Id.* Further still, "there was a lack of *sufficient*

[7] The court reviewed the claim under the more stringent standard in federal habeas proceedings, which is subject to two layers of judicial deference. *Coleman v. Johnson*, 566 U.S. 650, 651 (2012) (Noting that, under the Antiterrorism and Effective Death Penalty Act of 1996, a federal court may not overturn a state court decision rejecting a sufficiency of the evidence challenge simply because the federal court disagrees with the state court, but only if the state court decision was objectively unreasonable).

additional incriminating evidence, circumstantial or otherwise, to allow a rational juror to find guilt beyond a reasonable doubt." *Id*. (emphasis added). Accordingly, even if the defendant "touched the folder at some indefinite time with his left hand, and there is evidence the robber carried the folder at the time of the crime in his left hand," the prints were insufficient to prove the defendant was the perpetrator of the crime. *Id.* at 905. The federal court concluded that, even viewed in the light most favorable to the prosecution, the evidence was insufficient to prove guilt beyond a reasonable doubt. *Id.* at 905-06. To conclude that the defendant's fingerprints were left on the folder and paper during the robbery was "unreasonably speculative." *Id.* at 906.

The State's case here is even weaker. In *Travillion*, the robbery victim gave a partial description of the offender, which matched the defendant. *Id.* at 899. Moreover, the person who committed the robbery was seen carrying (and thus touching) the manilla folder; in contrast to the current case, there was no direct evidence the burglar handled the headphone case.

But most importantly, there is no additional incriminating evidence to tip the scales in the State's favor, which the *Travillion* court found to be a fatal deficiency. Slowinski testified he had never seen Cline before (R. 144), and the State offered no evidence anyone ever saw Cline near Slowinski's apartment the day of the burglary. In fact, when police interviewed Cline, he told them he had no reason to be anywhere near Slowinski's address. (R. 184). The State offered no evidence Cline possessed any of the numerous items taken from Slowinski's apartment. Even looking at this case in the light most favorable to the State, the

evidence here is less than *Travillion*. It would be even more unreasonably speculative – if not pure conjecture – to conclude, beyond a reasonable doubt, Cline left the partial print on the headphone during the burglary.

Similarly, in *Mikes*, the Ninth Circuit Court of Appeals found similar fingerprint evidence insufficient to sustain a conviction. 947 F.2d at 361. There, the defendant was convicted of murder of a man in the basement of a fix-it shop. *Id.* at 355-56. The victim had been beaten to death by one of three chrome posts that were originally part of a disassembled turnstile that the victim had purchased about four months earlier. *Id.* at 355, 359. At the scene, police lifted a total of 46 prints; fingerprint experts tied six of 16 identifiable fingerprints to the defendant, which came from two of the chrome posts. *Id.* 355, 358

The court found that the evidence was insufficient. *Mikes*, 947 F.2d at 961. The court reasoned that if the prosecution's case hinged on the theory that the defendant handled a certain object while committing the crime, "the record must contain sufficient evidence from which the trier of fact could reasonably infer that the fingerprints were in fact impressed at that time and not at some earlier date." *Id.* at 356-57.

The court emphasized that since it was the State's burden to place the defendant at the scene of the crime when the crime occurred, the State had to offer some evidence to "permit the factfinder to determine *when* the fingerprints were impressed; otherwise, any conviction would be based on pure speculation." *Id.* at 357. The court rejected the government's argument that the posts were inaccessible to the public so prints could only have been left them when the

defendant he committed the murder. *Id.* at 358-59. Because the posts were part of a turnstile that could have been touched by many when it was in use and then had been offered for sale in a hardware store, the court observed that the posts could have been "handled by others" so that prints could have been left anytime before the murder. *Id.* at 359. Most importantly, the court stated that "a defendant need not explain how or when his fingerprints were placed on the object in question; that burden lies elsewhere." *Id.* at 359 (citing *Borum v. United States*, 380 F.2d 595, 597 (D.C. Cir. 1967)).

As in *Mikes*, the State in the current case offered no evidence as to when the partial print may have been left on the headphones case, how long it could have been on the case, or how long fingerprints can last once they are left. The State's claim that the print could have only been left at the time of the burglary is pure speculation. (St. Br. 20-21). And as the *Mikes* court noted, it is not incumbent upon Cline to offer this evidence, it is the State's. 947 F.2d at 359; *see also People v. Murray*, 2019 IL 123289, ¶ 30.

There were other ways to allow for a reasonable inference a wayward print was left during a burglary, but those too are absent here. That is how this case deviates from *People v. Ford*, 239 Ill. App. 3d 314 (5th Dist. 1992); (St. Br. 12). In *Ford*, following a burglary, investigators found a fingerprint on a jewelry box they matched to the defendant. *Id.* at 317-18. The victim testified she "never" had taken the box out of her home and never gave anyone permission to touch it. *Id.* These facts allowed a reasonable inference that the print on it could only have been left during the burglary. *Id.* at 318.

Unlike *Ford*, the State cannot satisfy the "temporal proximity criterion" with the victim's testimony as Slowinski *never* testified he always left his headphones case at home. *Id.* at 318. The State never elicited any other evidence that would allow a reasonable inference that the print could have only been left during the burglary. To conclude that Cline left his print on this easily portable object only during the burglary absent any evidence the small case never left the apartment, like in *Ford*, is speculative at best. Thus, the State's evidence fails to prove the temporal proximity criteria, even viewing it in the light most favorable to the State.

Notably, Officer Gutierrez did not find any other prints in the apartment. (R. 153). Had Gutierrez found a print somewhere else – on the damaged, broken-in door, or some other non-moveable object, like a chest of drawers or refrigerator – perhaps a reasonable inference could be made that Cline left the prints during the burglary and not at any other time. Or, if police traced any of the stolen items back to Cline, it might add up and meet the burden. But none of that evidence existed in this case. Since the State had to prove the print was Cline's *and* he left it during the burglary, it cannot rely on speculation to satisfy either element. *See Travillion*, 982 F.2d at 906. The State's evidence was insufficient to prove Cline left the print at the time of the burglary, and thus insufficient to prove him guilty of residential burglary.

Lastly, the State's reliance on the facts of *People v. Rhodes*, 85 Ill. 2d 241 (1981), is misplaced as there was more evidence presented at trial then in the current case. (St. Br. 21-22). In *Rhodes*, this Court addressed three separate cases,

all which hinged in some way upon fingerprint evidence. 85 Ill. 2d at 245-48. Relevant here – and the particular facts the State cites for support (St. Br. 20) – was that of defendant Van Zant. *Rhodes*, 85 Ill. 2d at 247-48. After a burglary, during which the victim's television set was taken, a print was found on the bottom of a clock radio that was moved from the bedroom to the kitchen. *Id.* at 247-48. A fingerprint technician compared the print to Van Zant's fingerprint card and determined the recovered latent print matched Van Zant's left middle finger. *Id.* The jury found Van Zant guilty of burglary. *Id.* The appellate court reversed his conviction, finding he was not found guilty beyond a reasonable doubt, but this Court reversed the appellate court and upheld his conviction. *Id.* at 245, 250.

There was more evidence then just a fingerprint, however, as a girl who was playing in the area testified she saw a man matching Van Zant's description carrying a TV while running from the back of the burgled house. *Id.* at 251-52 (Simon, J., concurring in part and dissenting in part.); *see also People v. Van Zant*, 84 Ill. App. 3d 355, 357 (3d Dist. 1980). In upholding Van Zant's conviction, this Court acknowledged the identification testimony was "inadequate to support the conviction" on its own and thus reliant upon the fingerprint match; which it asserted, without explanation, "could only have been impressed at the time of the commission of the offense." *Rhodes*, 85 Ill. 2d at 247, 250.

While the girl's description of the burglar was "inconclusive" (*Id.* at 251 (Simon, J., concurring in part and dissenting in part), it still matched Van Zant's description so there was a partial identification to go along with the fingerprint match on an easily moveable object. That was more evidence then the State has

in this case, which is a critical distinction as "[t]here is no currently accepted method for determining the age of a fingerprint." Samuel Cadd, et al., *Fingerprint composition and aging: A literature review*, 55 Science & Justice 219, 220, 234 (2015) (reaching conclusion after conducting a literature review and discussing recent findings) (article included as Appendix A because not available online).

Here, there is *no* supporting identification evidence that Cline – or anyone remotely resembling him – was seen in the area of Slowinski's apartment. Had there been, then – coupled with Dennewitz's testimony – it might be a more reasonable inference than speculation and conjecture that Cline was the burglar. Moreover, a clock radio and headphones case are not the same thing. A clock radio plugged in next to a bed is inherently meant to be put in a place and undisturbed; headphones and their protective cases are meant to be portable so that people can use them in places in and outside a home. *Cline*, 2020 IL App (1st) 172631, ¶ 40 (Walker, J., specially concurring).

Lastly, the State correctly maintains that its evidence does not need to rule out every reasonable hypothesis of innocence. (St. Br. 21-22). But to sustain a conviction that evidence must allow a reasonable inference of guilt. And Cline does not need to prove he left the print on the case innocently at some prior time; instead, it was the State's burden to prove he left it while committing the burglary. That is why some supporting evidence – such as the identification discussed from this Court's decision in *Rhodes* – is necessary to tip the scales. Even an inconclusive identification can bolster a fingerprint match to meet the State's burden, since the sum is greater than the parts. *See Rhodes*, 85 Ill. 2d at 246, 250. Here, the

State has nothing but the part, and it cannot prove Cline guilty beyond a reasonable doubt even viewed in the light most favorable to it.

The State offered no evidence to establish that the partial print, even if Cline's, was left during the course of the burglary. Without any proof to satisfy the temporal proximity requirement, the State cannot sustain its burden, even viewed in the light most favorable to it. Thus, this Court should affirm the appellate court's reversal of Cline's residential burglary conviction.

CONCLUSION

For the foregoing reasons, John Cline, defendant-appellee, respectfully requests that this Court affirm the appellate court's reversal for his conviction of residential burglary.

Respectfully submitted,

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CERTIFICATE OF COMPLIANCE

I certify that this brief conforms to the requirements of Rules 341(a) and (b). The length of this brief, excluding the pages or words contained in the Rule 341(d) cover, the Rule 341(h)(1) table of contents and statement of points and authorities, the Rule 341(c) certificate of compliance, the certificate of service, and those matters to be appended to the brief under Rule 342, is 36 pages.

/s/Christopher G. Evers
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APPENDIX TO THE BRIEF

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Review

Fingerprint composition and aging: A literature review

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ABSTRACT

Fingerprints have a key role in criminal investigations and are the most commonly used form of evidence worldwide. Significant gaps remain however, in the understanding of fingerprint chemistry, including enhancement reaction mechanisms and the effect of environmental variables and time on composition. Determining the age of a fingerprint is also a relatively unexplored area. A successful method, with reliable and quantitative estimates, would have numerous advantages. Previous unreliable methods have predominantly focused on enhancement success based on physical and chemical changes.

This review explores variations in composition due to donor characteristics and environmental variables, and identifies gaps for further research. We also present a qualitative and quantitative summary of the effect of time on composition. Kinetics are presented where known, with summary schematics for reaction mechanisms. Previous studies exploring methods for determining the age of a fingerprint are also discussed, including their advantages and disadvantages. Lastly we propose a potentially more accurate and reliable methodology for determining fingerprint age based on quantitative kinetic changes to the composition of a fingerprint over time.

Contents

Abbreviations: DFO, 1,8-diazafluoren-9-one; GC–MS, gas chromatography–mass spectrometry; LC–MS, liquid chromatography–mass spectrometry; MALDI-MSI, matrix-assisted laser desorption/ionisation mass spectrometry imaging; SIMS, secondary ion mass spectrometry; UV, ultra-violet light/radiation; VMD, vacuum metal deposition

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1. Introduction

Fingerprints are one of the most important forms of physical evidence in criminal investigations [1] and the most commonly used forensic evidence worldwide [2]. Fingerprint examination cases typically match or outnumber all other forensic casework combined [2], with approximately ten times as many cases solved using fingerprint evidence compared to DNA [2].

Previous research exploring fingerprint composition has been within three key areas [3]. Recent advances have focussed on the development of novel enhancement methods and the optimisation of existing reagents [4–11]. Secondly, research has explored intelligence gathering through individualisation from the intrinsic composition. Recent advances in this area are critically examined in this review, including the ability to identify donor age, gender, and race from fingerprint composition [12–26]. Extrinsic composition has also been explored, including drugs, cosmetics, and food contaminants [12,27–32], but is not discussed in this review. Readers are directed elsewhere for further information regarding contaminants. Thirdly research has explored the potential for fingerprint age determination through changes to composition over time [20,33–41]. There are currently no accepted analytical methods for reliably determining fingerprint age. Due to the unreliability of proposed methods, investigators have always distanced themselves from age determination, as speculation is subject to considerable error and is therefore highly dangerous to the reputation of an examiner [42]. The potential to determine a timeframe during which a fingerprint was deposited is however a highly relevant factor in criminal investigations. Convictions can depend on the ability to prove beyond reasonable doubt whether a fingerprint was deposited when a crime was committed or from a previous legitimate visit, as is often claimed by the defence team [1,2]. Several possible methods have been recently proposed, which have focused on physical and chemical changes to fingerprints over time, as well as the effect of these changes on subsequent enhancement with powders or chemical techniques.

This review aims to critically discuss recent findings regarding fingerprint composition and age determination, with a particular focus on the effect of time on composition. Novel developments in the identification of donor characteristics are also discussed, as well as the effect of environmental variables on fingerprint composition. Additionally, this review contains a critical appraisal of fingerprint age determination methods and we propose an optimum methodology based on quantitative changes to the composition of a fingerprint over time. Lastly this review identifies key gaps in scientific knowledge and discusses future requirements and perspectives for fingerprint research. Numerous terms including 'fingerprint', 'fingermark' and 'latent print' [43] have been used in previous research. To minimise confusion this review will use 'fingerprint' throughout, as chemical analysis has only been applied to fingerprints. Additionally, determination of fingerprint age is used to mean identifying when a fingerprint was deposited; opposed to aging a fingerprint or fingerprint aging, which is used to mean leaving a deposited fingerprint to change with time.

2. Fingerprint composition

A fingerprint is composed of sweat secretions transferred onto a substrate, resulting in an impression of the ridge pattern or fingerprint left behind [44]. Sweat composition has been studied extensively from a medical or dermatological view point [45–55], although fingerprint composition is more complex. Fingerprints contain a mixture of substances originating from the epidermis, the secretory glands in the dermis (in a combination of some or all of the three sweat types), intrinsic components including metabolites and traces of medications and drugs; and extrinsic contaminants, such as blood, dirt and grease, make-up, food contaminants, moisturisers, and hair care products [3,12,27–29,31,32,32,56]. The intrinsic and extrinsic constituents can vary significantly between individuals (intervariability), as well as from the same individual from day to day (intravariability) and at different times on the same day [24].

The intrinsic components of a fingerprint are comprised of 95–99% water [57] and organic and inorganic compounds forming a complex emulsion in a three-dimensional matrix [56]. The eccrine component of the fingerprint is composed of approximately 98% water, as well as organic and inorganic compounds [16,58], as shown in Table 1. Studies to date have quantified 20 amino acids in fingerprints [59–66], as shown in Table 2.

Sebaceous sweat is composed of numerous organic compounds, as shown in Table 3. The majority are lipids [56] including fatty acids, glycerides and long chain fatty acid esters; as well as squalene, sterols; such as cholesterol, and numerous lipid esters [16]. A summary of the organic and inorganic components from all three sweat glands is shown in Table 4.

The composition of a fingerprint is subject to numerous factors, which affect the initial composition at both deposition and after aging over time. These are simply demonstrated in the triangle of interaction [68], which demonstrates the relationship between fingerprint composition, the substrate and the environment, as shown in Fig. 1.

These factors affect fingerprint composition in two stages, classed in this review as the '*deposition stage*' and the '*aging stage*', as shown in Fig. 2, and result in a particularly complex and variable matrix [3].

The *deposition stage* is affected by donor characteristics, including age, gender, race and diet; the deposition conditions, including deposition action, contact time, angle and pressure; and the nature of the substrate, including porosity, curvature and surface texture [3]. Due to

Table 1
Organic and inorganic constituents (average values) in eccrine sweat based on [3,58].

Organic (major)		Organic (trace)	Inorganic (major)		Inorganic (trace)
Amino acids	1.45 mg/L	Creatine	Chloride	3.5 g/L	Magnesium
Proteins	200 mg/L	Creatinine	Sodium	3.3 g/L	Zinc
Glucose	3.5 mg/L	Glycogen	Potassium	0.2 g/L	Copper
Lactate	3.15 mg/L	Uric acid	Iron	3.5 mg/L	Cobalt
Urea	0.75 mg/L	Vitamins	Calcium	2 mg/L	Lead
Pyruvate	0.079 mg/L		Bicarbonate	107 mg/L	Manganese
			Sulphate	10 mg/L	Molybdenum
Organic (lipids)			Phosphate	1.4 mg/L	Tin
Fatty acids	0.055 mg/L		Fluoride	69 μg/L	Mercury
Sterols	0.065 mg/L		Bromide	35 μg/L	
			Iodide	0.85 μg/L	

considerable variations between donors, deposition methods and substrates, the initial composition can vary significantly.

The *aging stage* affects composition immediately after deposition, producing the aged composition encountered at enhancement [3]. During the aging stage fingerprints are affected by the substrate, environmental conditions, such as temperature, humidity and light levels; the enhancement techniques, such as physical, physico-chemical or chemical methods; and the time elapsed since deposition, with longer aging periods resulting in greater degradation of fingerprint components. The final aged composition is therefore a combination of all of the factors from both the deposition and aging stages.

2.1. Variation with donors

Fingerprint composition can vary significantly between donors, due to differences including gender, age and race, as well as medication, psychological state, health, metabolism and diet [3].

Composition can be affected by gender, although there have been differing conclusions as to the significance of the variations observed [16,19,69,70]. Recent findings in small scale experiments indicate fatty acids tend to be present in higher concentrations in male donors, such as saturated C15, C16 and C17 acids [16,19,70], although wide variations in composition were observed due to the sampling protocol [16]. Studies have shown sterols and sterol esters tend to be more concentrated in female donors [58], as well as amino acids, such as alanine, glycine and serine [16,71], although this variation is not statistically significant as only 20 donors were sampled [71]. One study suggested wax esters differ in concentration between male and female donors [72], although this has not since been confirmed and wax esters remain largely unexplored. Larger investigations with increased donors have identified no "statistically significant gender effects" [19]. Additional large scale research is necessary to investigate these variations further.

Donor age can also affect fingerprint composition and considerable research has explored differences between children and adults [15,17,18,25,53,72–75]. Fingerprint composition can alter significantly between birth, puberty and old age [58], as fingerprints from donors prior to puberty are composed of eccrine related compounds, while fingerprints from more developed donors contain sebaceous components, similar to adult donors [23,52]. This difference in volatile components affects the longevity of the fingerprint [3], as a child's fingerprint may completely disappear in as little as 48 h, compared to a week for an adult fingerprint [15]. One study exploring the fingerprint composition of 6 father–son pairs suggested fingerprint longevity is affected by the rate of sebum excretion, which affects the concentration of all sebaceous compounds present in a fingerprint [17]. Studies have indicated this rate is affected by donor age, and causes variations in composition, including fatty acid concentrations, the ratio of wax esters to cholesterol, and the concentrations of cholesterol and carbonyl esters [17,76]. Organic compounds also change with donor age, as a high concentration of lipids have been identified in adult fingerprints, including squalene, wax esters and branched fatty acids [17]. These fingerprints are less volatile compared to fingerprints from child donors (pre-pubescent), which contain cholesterol, cholesterol esters, straight-chain fatty acids and long chain fatty acid esters [17], primarily due to "inactive sebaceous glands" [19]. However these conclusions were obtained from the differences between only 132 fingerprints from 6 children and 6 adults.

Puberty causes numerous changes to fingerprint composition, as the proportion of endogenously synthesised sebaceous lipids, such as squalene, wax esters, and Δ6 fatty acids increases, while the proportion of exogenous lipids, such as cholesterol, Δ9 fatty acids, and the unsaturated omega-6 C18 fatty acid (linoleic acid) decreases [3], as shown in Fig. 3. After puberty, findings indicate there are fewer changes until after middle age [58]. One recent study explored the fingerprint

Table 2
Amino acid composition in latent fingerprints (percentage relative to serine) based on [56,58,67].

Amino acids	Hadorn [64]	Hamilton [65]	Oro [66]	Average	St. dev.
Serine	100	100	100	**100**	0.0
Glycine	54	67	59	**59**	6.1
Ornithine	45	32	45	**41**	6.1
Alanine	35	27	28	**28**	5.4
Aspartic acid	11	22	22	**20**	5.9
Threonine	9	17	18	**16**	4.4
Histidine	13	17	14	**15**	1.8
Valine	10	12	9	**10**	2.1
Leucine	7	10	10	**9**	1.7
Isoleucine	6	8	8	**7**	1.2
Glutamic acid	12	8	5	**7**	3.9
Lysine	5	10	–	**8**	4.1
Phenylalanine	5	7	5	**6**	1.0
Tyrosine	3	6	5	**5**	1.3

Table 3
Organic composition of sebaceous secretions based on [3,58].

Organic (major)	Organic (trace)	
Triglycerides	30–40%	Aldehydes
Fatty acids	15–25%	Ketones
Of which:		Amines
saturated	50%	Amides
monounsaturated	48%	Alkanes
polyunsaturated	2%	Alkenes
Wax esters	20–25%	Alcohols
Squalene	10–12%	Phospholipids
Cholesterol	1–3%	Pyrroles
Cholesterol esters	2–3%	Pyridines
		Piperidines
		Pyrazines
		Furans
		Haloalkanes
		Mercaptans
		Sulphides

Table 4
Constituents of gland secretions.

Source\constituents	Inorganic	Organic
Eccrine glands	Chlorides	Amino acids
	Metal ions	Urea
	Ammonia	Lactic acids
	Sulphate	Sugars
	Phosphate	Creatinine
		Choline
		Uric acid
Sebaceous glands	–	Glycerides
		Fatty acids
		Wax esters
		Sterol esters
		Sterols
		Squalene
		Hydrocarbons
		Alcohols
Apocrine glands	Iron	Proteins
		Carbohydrates
		Cholesterol

composition of 63 children between 2 and 11, and determined carboxylic acid salts are relatively stable within fingerprints compared to their esters [73]. It was suggested these acid salts could be used as an enhancement target in children's fingerprints after greater periods of time than currently possible [73].

These differences in composition indicate that it may be possible to distinguish fingerprints from donors of different ages. Some research has explored this possibility through the use of calibration curves to estimate a donor age range [17,18], although larger studies are required to support these conclusions with statistically significant results.

Minimal research has explored differences in composition between donors of different races, despite the potential for advantages in intelligence. A small scale study of 37 donors concluded that the ratio of several fatty acids to their respective methyl esters was significantly different for donors of different races [24]. The Δ6 FAME from the C18 monounsaturated omega-9 fatty acid was found to have a highly variable ratio to the respective unsaturated C18 fatty acid in each race classification [24]. The greatest difference was observed between Caucasian and African American males, although the study acknowledges this finding could be due to the small sample size. Further research with a larger donor set is needed to determine the "true legitimacy of the observed trends" [24].

Diet may also affect composition, as a recent small-scale study identified increased levels of alanine, glycine and serine from vegetarian donors, as well as higher concentrations of saturated C17 and both saturated and unsaturated C18 fatty acids [16].

Previous research has clearly identified the possibility of using fingerprint composition to determine several donor traits, but further large scale research is needed before composition can be used for accurate and reliable individualisation of donor characteristics.

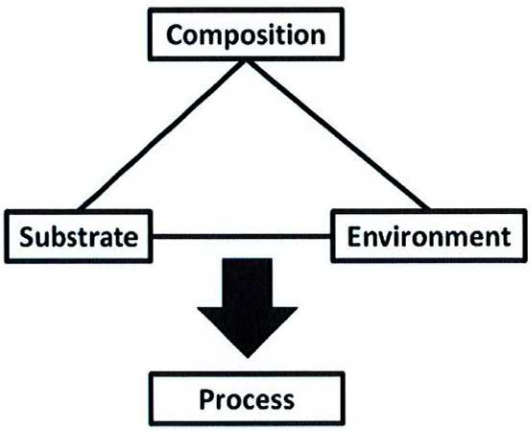

Fig. 1. Triangle of interaction based on [68].

2.2. Other variations

Fingerprint composition is also affected by the deposition conditions, the nature of the substrate and enhancement methods.

The deposition conditions affect the concentration of components within the fingerprint at the *deposition stage* [3,16,20,26,59,77,78]. These conditions include the pressure of the deposition, the duration of the contact, the dimension of the finger in contact with the substrate, the digit used for deposition, and how recently the donor washed their hands [3].

The substrate also affects fingerprint composition predominantly during the *aging stage* [3]. Research has identified high porosity creates adhesion forces between the substrate and the fingerprint, causing greater penetration of components into the substrate [79,80], as shown in Table 5. Findings indicate fingerprints deposited on non-porous surfaces are more susceptible to damage, due to increased exposure to environmental factors [80,81]. Chemical reactions can also occur between the substrate and fingerprint, such as metal corrosion by ionic salts [82]. One study explored 10 metals and determined high concentrations of chloride ions enhanced corrosion of noble metals, such as silver and gold [83]. Research suggests surface texture may also affect composition, as well as the physico-chemical structure, curvature, temperature, electrostatic forces and surface free energy [3], although there have been no studies exploring these factors specifically.

Enhancement techniques also affect fingerprint composition in the *aging stage*. The significance of the effect depends on the fingerprint age [3], although enhancement rarely takes place immediately after deposition. Several studies have explored the effect of indanedione, cyanoacrylate fuming and aluminium powder on composition [35,84–86]. One study focused on changes to squalene, cholesterol and the C14 saturated tetradecanoic acid within fingerprints from 7 donors [35]. Cyanoacrylate fuming and aluminium powder both had no effect on composition, although the powder contaminated the sample [35]. Indanedione enhancement contaminated the fingerprints due to the solvent and through reaction with amino acids. The enhancement reduced the concentrations of squalene, cholesterol and tetradecanoic acid [35]. An awareness of these changes due to enhancement is important, if analysis of composition is to be carried out after enhancement.

3. Effect of time

The composition of a fingerprint is highly variable [3], as significant changes occur after deposition through surface interactions and various decomposition and oxidative mechanisms [14]. Fingerprint composition can be separated into two parts:

1. the *initial composition*, at deposition where compounds within the digit residue are transferred to the substrate in the *deposition stage*
2. the *aged composition*, containing the remaining initial compounds and the degradation products following the *aging stage*.

Comparatively little research has explored changes between the initial and aged compositions and the rate of change with time [16]. Some research has explored the effects of time on reaction mechanisms and kinetics for specific compounds, including amino acids, proteins, fatty acids, squalene, cholesterol and wax esters [3]. This research can be divided into two areas:

1. The development of enhancement techniques [7,31,33,36–39,47,48,132,140]
2. The development of fingerprint age determination methods [7,36,39,51,67,79]

Increased knowledge of fingerprint composition allows for increased comprehension of the chemical mechanisms that occur between

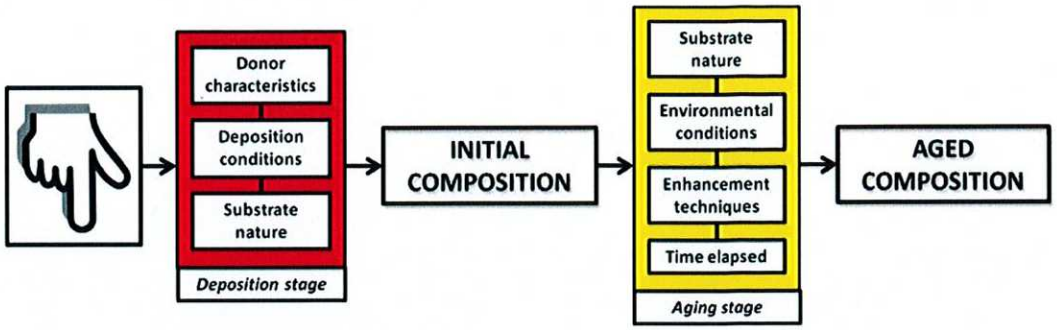

Fig. 2. The variables that affect fingerprint composition prior to and after deposition based on [3].

enhancement reagents and their target compounds, as well as how they interact within the 3D matrix. This allows for improvements to both existing reagents and novel developments with a high level of effectiveness for both fresh and old fingerprints [3]. Existing reagents can vary in their effectiveness on aged fingerprints, such as Nile red which is generally ineffective on fingerprints more than a few days old, due to loss of moisture preventing the partitioning mechanism from taking place [58]. Oil Red O is more effective on fingerprints less than four weeks old, due to diffusion of water-soluble components and degradation of fragile components with time [87]. Physical developer is more effective on aged fingerprints [87].

Fingerprint composition changes through various chemical, biological and physical processes resulting in the *aged composition*. The rate and method of the aging process can vary significantly [88], with initial compounds lost through various processes including degradation, drying, evaporation, metabolism, migration, oxidation and polymerisation [3]. Recent findings exploring these changes are critically discussed in the following sections.

3.1. Loss of moisture & mass

Over time the volatile components of a fingerprint evaporate out of the residue [89,90]. The fingerprint becomes increasingly viscous causing an initial large change in thickness [85]. Findings suggest the ridges become increasingly brittle and topographically irregular [85], through increased susceptibility to physical erosion from friction and air currents that cross the fingerprint surface [89]. As water is lost, the fingerprint becomes less receptive to chemical enhancement, as the remaining mixture of organic and inorganic compounds accumulates within a waxy layer, decreasing the surface area available for contact with enhancement reagents [74].

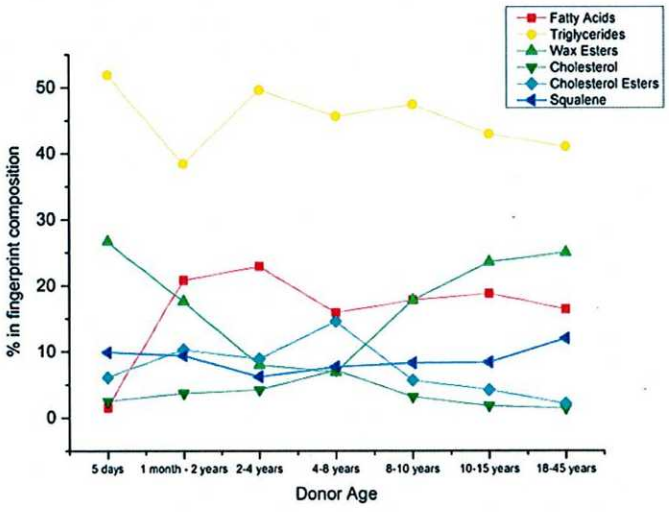

Fig. 3. Effect of donor age on fingerprint composition [58].

The mass of a fingerprint decreases over time, as volatile components are lost. A fingerprint can lose nearly 98% of its original weight within 72 h of deposition [91]. One study identified a loss of mass up to 85% after aging for two weeks [74], possibly due to loss of moisture [3]. An initial increase in detected material has been observed, possibly due to component decomposition [14], although this has not been confirmed in any other studies.

3.2. Organic & inorganic compounds

Both organic and inorganic compounds within a fingerprint are significantly affected by time, although little research has explored this effect [3].

3.2.1. Organic compounds

The majority of research exploring the effect of time on fingerprint composition has focused on lipids, discussed in Section 3.3, although some research has explored other organic compounds.

Research within the last decade determined *amino acids* are relatively stable over time, predominantly due to enhancement success with amino acid targeting reagents on older fingerprints [92]. It was suggested a relationship between the amino acids and the porous nature of the cellulose substrate may have assisted with the preservation [3]. Other research using paper substrates identified a decrease in mass of 0.083 mg/cm^2 to 0.046 mg/cm^2 after 236 days [93]. This indicates that although amino acids may not be completely stable over time, enhancement is still possible, either because amino acid concentration remains high enough for successful reaction or due to the high sensitivity of the enhancement methods. One study exploring the effect of time on *proteins*, used antibodies with albumin to enhance fingerprints on porous substrates. Successful enhancement was possible with both freshly deposited and aged fingerprints (up to 130 days) [94], possibly due to the stability of albumin on paper [3]. Research has also identified a significant decrease in concentration of *urea* from 0.083 mg/cm^2 to 0.028 mg/cm^2 over a period of 236 days [93].

3.2.2. Inorganic compounds

Minimal research has explored the effect of time on inorganic components. The concentration of *chloride* was observed to decrease slightly from 0.223 mg/cm^2 to 0.217 mg/cm^2 over 236 days [93]. This change could explain why some enhancement techniques, such as silver nitrate which targets chloride ions, are less effective on older fingerprints [3]. This concentration decrease could also be due to diffusion into the substrate over time [95]. Preliminary research suggested changes to this diffusion pattern could be used for exploring fingerprint age [96], although diffusion is significantly affected by environmental variables, such as the storage conditions of the substrate [3], yielding unreliable highly subjective results. As the research findings determined this concentration decrease was not a significant change however, additional

Table 5
Effect of substrate on the absorption of fingerprint residue based on [3,79,80].

Substrate nature	Eccrine compounds	Sebaceous compounds	Examples
Porous	Rapidly absorbed	Slowly absorbed	Paper, cardboard, cotton, wood
Semi-porous	Absorbed slower than porous	Very slowly absorbed (slower than eccrine)	Glossy papers, plastics, laminated wood
Non-porous	Not absorbed – compounds remain on surface until degradation occurs		Plastics, glass, metal, rubber, painted wood

research is required to explore the effect of time further on inorganic compounds within fingerprints.

3.3. Lipids

After deposition, degradation processes result in changes to fingerprint composition over time [14,16]. Unsaturated compounds undergo several shortening and oxidising degradation processes, removing the unsaturated moiety. This removes a target for enhancement reagents, such as fluorescent tags [74]. Previous research exploring these changes has primarily focused on lipid components within fingerprints, as these tend to decrease significantly in concentration over 30 days, such as fatty acids, wax esters, triglycerides, cholesterol and squalene [14,16,20,58,74,97,98]. These various degradation and decomposition processes result in the formation of smaller oxidation products; the details of which are outlined in the following sections.

3.3.1. Fatty acids

Both saturated and unsaturated fatty acids tend to be present in all fingerprints [14]. *Saturated fatty acids* remain relatively stable over time, with one study determining C16 and C18 acids were relatively stable over a 60 day aging period [74]. The concentration of short chain saturated fatty acids was observed to increase over the first 15 days, through the degradation of longer chain fatty acids [14]. The C14 saturated acid increased in concentration over a 20 day aging period, followed by a decrease back to original levels or below after further aging [14], although only 5 male donors were used to obtain these conclusions. Other short chain fatty acids, such as C6, C8 and C9 acids are also present in greater concentrations in aged samples, where they undergo additional reactions to break down further or evaporate [56].

Several different theories have been proposed to explain this increase in fatty acid concentration over the first month [14], as shown in Fig. 4, although no theory has since been confirmed. One theory suggests an increase in two separate phases, with the initial increase over the first 7 to 10 days, followed by a slight decrease, and then phase two occurring between days 15 and 20 [14]. An alternate theory proposes a single concentration increase at different times depending on various factors, including the initial composition of the fingerprint [14]. A third theory proposes competing mechanisms of both production and loss, the equilibrium of which determines the concentration of fatty acids present [14].

It is suggested that the majority of fatty acids present in sweat originate from the hydrolysis of triglycerides in sebum [58]. This observed increase could therefore be due to the decomposition of wax esters and triglycerides, and the subsequent decrease could be due to the volatilisation or chemical degradation of fatty acids. This supports the theory of competing mechanisms at equilibrium within a fingerprint. Research exploring fatty acid production and loss is required to confirm which theory is correct, although enzyme lipolysis has been identified as a possible production mechanism, as triglycerides and methyl esters are broken down into fatty acids [99].

The concentration of *unsaturated fatty acids* has been observed to decrease with time, such as unsaturated C16 and C18 acids. Both acids are significantly reduced in concentration over a 30 day aging period, due to the unsaturated moiety being open to attack through aerobic and anaerobic degradation processes [74], as shown in Fig. 5. Research findings indicate anaerobic conditions cause hydrogenation processes, which transform unsaturated bonds, increasing the concentration of saturated fatty acids and decreasing the proportion of unsaturated fatty acids [100]. Aerobic degradation produces oxidised compounds, such as peroxide linkages, aldehydes and ketones, through a chain reaction process [101].

Tetracosane, a 24-carbon chain alkane, was identified in one study in samples of 'intermediate age' [14], indicating it may be an intermediate in the decomposition of longer chain compounds. No other study has identified this compound and further research is needed to explore possible formation and degradation mechanisms.

Saturated fatty acids remain in fingerprints for longer than unsaturated acids, predominantly due to the lack of a targetable functional group. Lower molecular weight compounds produced from fatty acid degradation are more volatile [58]. One study explored the decomposition of the unsaturated C18 acid over time and used the decomposition products to successfully distinguish three fingerprints of different ages using MALDI-MSI [97].

Further research exploring changes in fatty acid concentrations, as well as the various decomposition products that occur within a fingerprint is therefore clearly warranted, so as to fully understand the processes that occur over time after deposition.

3.3.2. Wax esters

Saturated lipids are less affected by change over time, resulting in higher levels of saturated compounds, such as wax esters [58]. This is predominantly due to the lack of a targetable functional group to aid

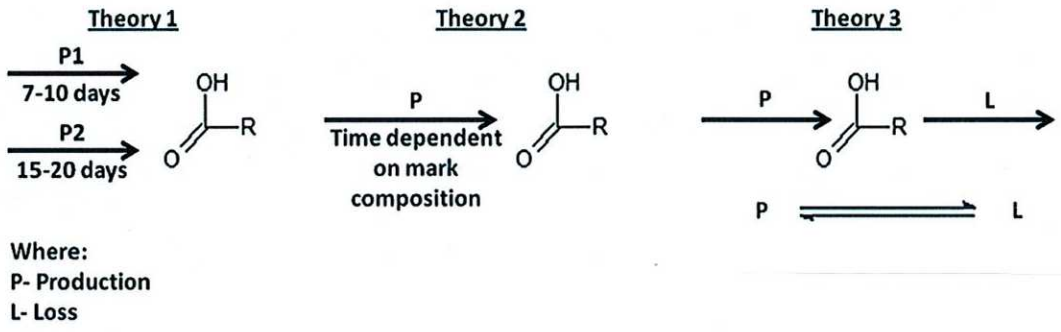

Fig. 4. Three theories for fatty acid concentration variations.

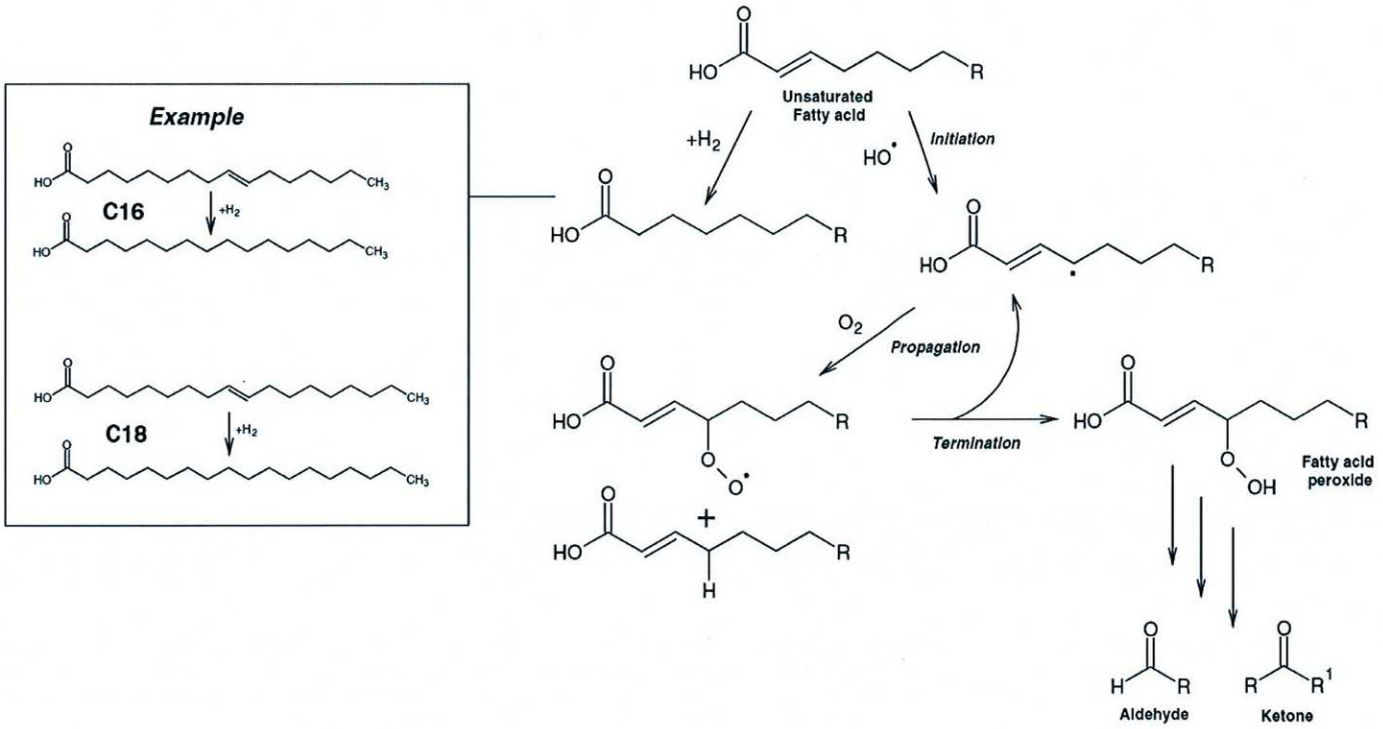

Fig. 5. Degradation of fatty acids through aerobic and anaerobic processes.

decomposition, which may also be why minimal research has explored wax esters in fingerprints. As an increase in the concentration of fatty acids could be due to the breakdown of wax esters [14], further research is clearly required to explore wax esters and their subsequent degradation products in more detail.

3.3.3. Triglycerides

Little research has explored the effect of time on triglycerides, although research in other areas has identified possible degradation mechanisms. Hydrolysis releases fatty acids from the glycerol backbone, resulting in a mixture of saturated and unsaturated fatty acids [100].

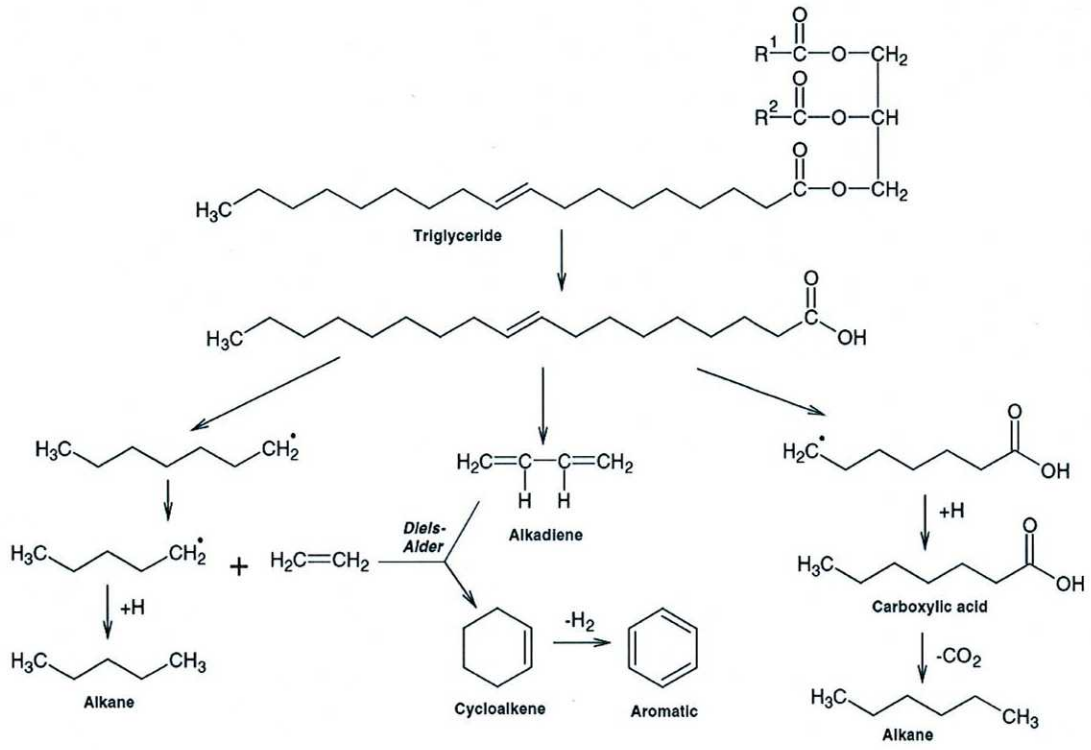

Fig. 6. Thermal decomposition of a generic triglyceride based on [100].

Thermal decomposition yields a number of compounds, including alkanes, alkenes, alkadienes, aromatics and carboxylic acids [100], as shown in Fig. 6. Decomposition mechanisms are particularly complex, predominantly due to the many structures and potential reactions of varying chain length triglycerides. Research to identify these compounds in fingerprints and their rate of formation would be particularly advantageous for the identification for novel potential targets for enhancement reagents.

3.3.4. Cholesterol

Cholesterol is the most abundant sterol in the body [16]. A small scale study detected cholesterol in all 24 fingerprints investigated and observed a decrease in concentration over time [20], although any decomposition products present were not identified. The focus of the study was on substrate effects and determined the rate of decomposition was dependent on substrate porosity, as concentration decreased at a slower rate on glass compared to polyvinylidene difluoride and did not show any change on porous microfilters over the time frame studied [20].

Few studies have investigated cholesterol decomposition [102], and research exploring changes to cholesterol in fingerprints have only observed a concentration decrease [20]. Research in other areas has determined cholesterol is susceptible to oxidation [103–105] and can form a large number of oxygenated products, including cholesterol oxides and oxysterols through 'autoxidation' [103,104]. The 8 most important [104] are shown in Fig. 7. Cholesterols can also be converted to cholesterol esters, through esterification of the A-ring hydroxyl by the carboxylate group of a fatty acid, as shown in Fig. 8.

One study determined the decomposition of pure cholesterol can be accelerated by triglycerides or fatty acids [104]. The study explored the effect of both saturated and unsaturated C18 fatty acids and determined that the cholesterol oxides formed; 3,5-cholestadiene and cholesta-3,5-dien-7-one, were different from those produced in the presence of triglycerides [104,105]. These oxygenated cholesterol products have not been identified in fingerprints of any age however.

The presence of cholesterol can also influence the decomposition of triglycerides [103], indicating that the stability of lipid components is influenced by numerous interactions among these components and/or their decomposition products. More research is clearly required to explore and identify cholesterol decomposition products within fingerprints, as well as the numerous interactions that occur with other compounds, due to the lack of current research in this area.

3.3.5. Squalene

Squalene is an unsaturated organic triterpene steroid precursor [74] and has been studied in some detail over the last decade [14,16,20,74,98]. Recent findings indicate squalene decomposes rapidly over time and is rarely detected in older fingerprints, such on glass substrates where it is almost undetectable after only one week [98]. The same study also used LC–MS to explore the effect of time and successfully identified a number of oxidation products [98]. The most fully oxidised forms were identified as hexanedioic and pentanedioic acids through oxidation in air [74,98], as shown in Fig. 9. Other intermediate products were identified including epoxides, ketones and a range of hydroperoxides. These included squalene mono-hydroperoxide (SQ-[OOH]) to the

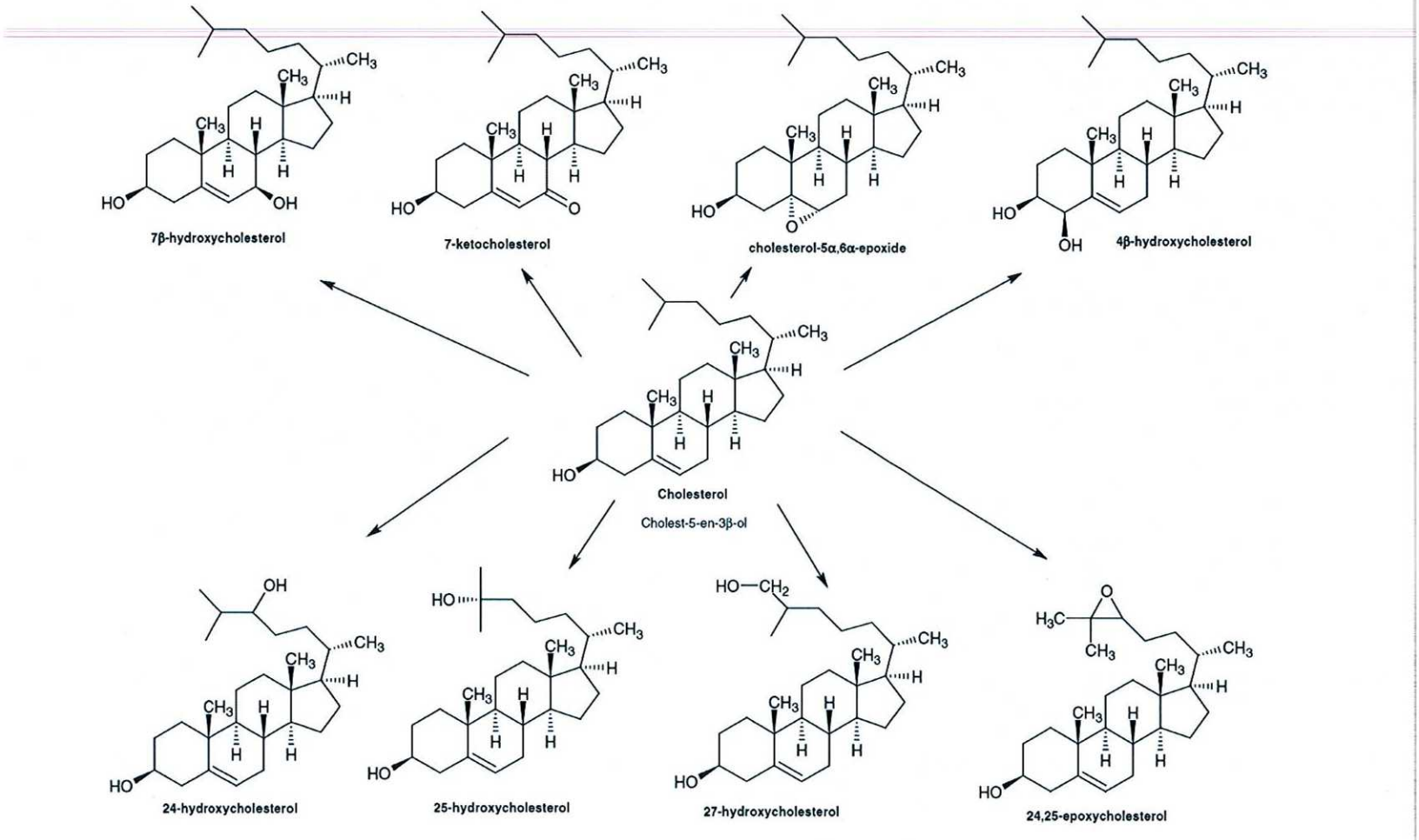

Fig. 7. Decomposition of cholesterol through oxidation to 8 key oxidised forms based on [103].

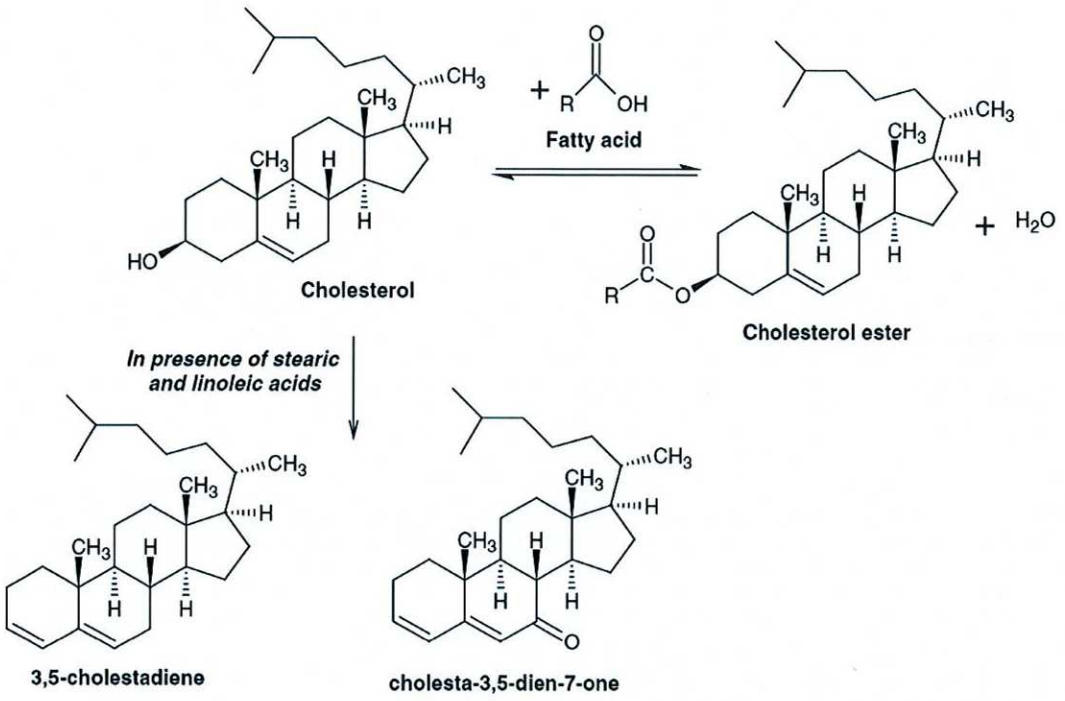

Fig. 8. Esterification of cholesterol to cholesterol ester and decomposition to 3,5-cholestadiene and cholesta-3,5-dien-7-one.

di- (SQ-$[OOH]_2$), tri- (SQ-$[OOH]_3$), tetra- (SQ-$[OOH]_4$), and squalene penta-hydroperoxides (SQ-$[OOH]_5$) [98].

Squalene tetra- and penta-hydroperoxides were still detectable after 20 days [98], indicating they are formed towards the end of the oxidation sequence. One study aged fingerprints for one month under ambient conditions and determined that 10% of each sample was composed of hydroperoxides [3,58]. Squalene epoxide in comparison was detected in freshly deposited marks and increased in concentration over 5 days from deposition [98]. It was undetectable after 7 days however, indicating squalene epoxide undergoes further decomposition [98].

Photo-oxidation was also identified as a decomposition method, as it produced very reactive, volatile products including malonaldehyde, formaldehyde, acetone and acetaldehyde [98], which are rapidly lost from fingerprints or undergo further decomposition reactions with other constituents. Acetaldehyde and acetone can be formed through a 6-methyl-5-hepten-2-one intermediate, which can also breakdown to form malonaldehyde [106]. Peroxides are formed through exposure to UV irradiation [107].

Squalene polymerisation through carbon–carbon bond formation has also been observed in one study, which identified the formation of a waxy solid and determined the presence of both higher and lower molecular weight products from the squalene parent compound [14,74].

Further research into the effect of time on squalene concentration, as well as the various decomposition and polymerisation products formed is clearly warranted, so as to fully identify and understand these changes.

3.4. Ratios of compounds

The initial composition of a fingerprint is used to determine the starting point of a potential aging curve [20]. This causes some difficulty when exploring the effect of time on composition, as there can be significant variation between donors. Research focusing on the amounts of specific components relative to each other is potentially more reliable and accurate for age exploration, as it does not require knowledge of the initial concentrations [20], which, in almost all circumstances, is not possible to establish. Successful identification of several compounds and observing their decomposition, allows for comparison of the concentration ratios, which can be used to explore the effect of time more accurately. One study used this method to compare relative concentrations of squalene and cholesterol through the relative peak areas [20]. The relative standard deviation of the ratio of the two (less than 20%) was significantly less compared to the standard deviation of the individual compounds (up to 80%) [20], indicating a more reliable comparison method. This also resulted in more reproducible results over time, as the squalene-cholesterol peak area ratio produced more accurate concentration changes over the first few hours of aging [20]. The use of compound ratios appears to yield more reliable data, which indicates further research is needed to explore this as a method, that has the potential to follow changes to the composition of a fingerprint in a more reproducible way than proposed by previous research [14,108].

Summary schematics of the decomposition processes identified in recent research, as well as degradation products of key compounds present in fingerprints are shown in Figs. 10 and 11. Reaction kinetics or rates of decomposition are not displayed, as these have not been successfully identified for most compounds of interest. Exploration of reaction kinetics requires significant further research, so as to identify reaction products and the rate at which they are formed.

4. Effect of environment

The composition of a fingerprint changes after deposition and is affected by three variables: *donor factors*, discussed in Section 2.1; *transfer conditions*, discussed in Section 2.2; and *environmental factors*, such as air circulation, atmospheric contamination, condensation, dust, friction (handling or other natural movement), humidity, light exposure, precipitation, temperature, ultraviolet and other radiation [14,34]. Fingerprints deposited at crime scenes are on a range of substrates both inside and are therefore subject to environmental variations, which can significantly affect how the composition changes over time.

4.1. Light exposure

Research has identified light exposure can affect composition. One study explored lipid changes over time under a number of different environmental conditions and determined fatty acids were lost less rapidly in dark conditions [26]. The concentration of the monounsaturated

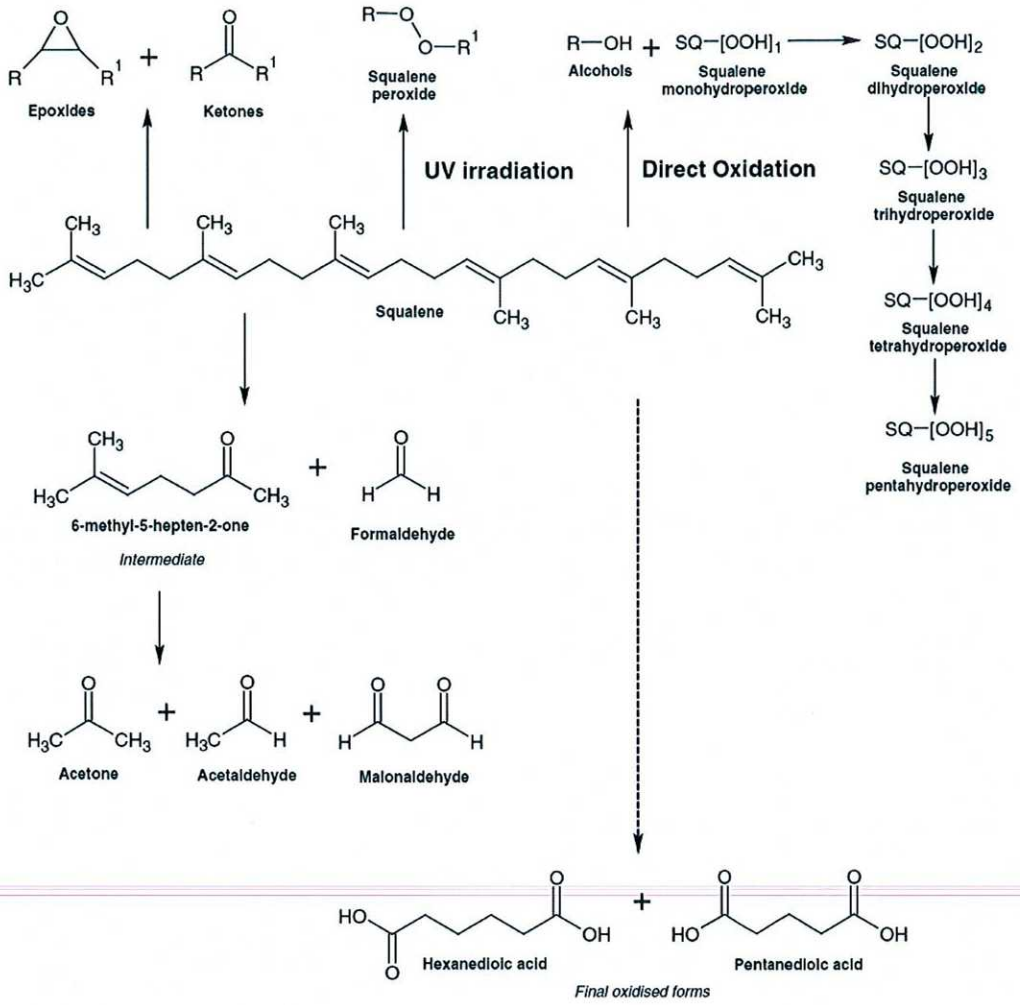

Fig. 9. Squalene decomposition through various processes including oxidation, UV irradiation and direct oxidation to hydroperoxides.

C18 fatty acid increased initially followed by a decrease in dark conditions, but not when aged in light conditions [14], suggesting different decomposition mechanisms occur under different levels of light [14]. Another study explored fingerprints over 1 month [108] and determined fingerprints in dark conditions showed a significant loss of cholesterol and saturated C16 and unsaturated C18 fatty acids [108], indicating decomposition mechanisms that are not light dependent. Results showed squalene concentration also decreased significantly over a 2 week aging period in light conditions [56,108], which is supported through the identification of photo-oxidation mechanisms [98], although squalene concentration decreased when aged in both light and dark conditions [14]. One study determined squalene is not detectable after 9 days in light conditions, compared to dark conditions where it is still detectable after 33 days, although at much lower levels than in freshly deposited fingerprints [14]. Several findings identified squalene decomposition occurs more rapidly in brighter conditions, particularly in the presence of UV radiation, such as in sunlight [14,16,98,107]. This is again supported by recent research determining a photo-oxidation mechanism, which results in the formation of squalene monohydroperoxide and squalene epoxide after only one day [98].

4.2. Temperature & humidity

Fingerprints can also be exposed to temperature and humidity after deposition, with higher temperatures increasing the rate of water loss [109].

Findings indicate high temperature results in increased degradation of amino acids compared to aging at room temperature [61,110]. The study explored pure compounds present in eccrine sweat and determined amino acids undergo thermal degradation as opposed to photo-degradation [110], as the seven amino acids monitored were all degraded after 3 min at 100 °C. These findings have not been replicated using fingerprints. Decomposition products have also been identified, including 3,6-dimethylpiperazine-2,5-dione from alanine and maleimide and 2,5-furandione from aspartic acid [61], as shown in Fig. 12. These decomposition products have been confirmed in several other studies and have been proposed as a possible source of fingerprint fluorescence after exposure to increased temperature [111,112]. One study identified the optimum temperature range to ensure successful enhancement using amino acid reagents as 20–35 °C [113]. The study concluded that if a fingerprint were exposed to heat for prolonged periods of time, enhancement would be much more difficult [113], presumably due to degradation of the amino acid target compounds.

Other compounds are also affected by temperature, such as urea which was identified to decompose more rapidly at higher temperatures [13] and esters which form lower molecular weight product compounds [13,73]. Acid salts are more resistant to higher temperatures and were still detectable, even after heating at 70 °C for 72 h [73]. The effect of temperature on cholesterol in fingerprints has not been explored, indicating further research to determine the effect of temperature on fingerprint composition is clearly warranted.

There has been very little research specifically exploring the effect of humidity on fingerprint composition, although studies suggest that the

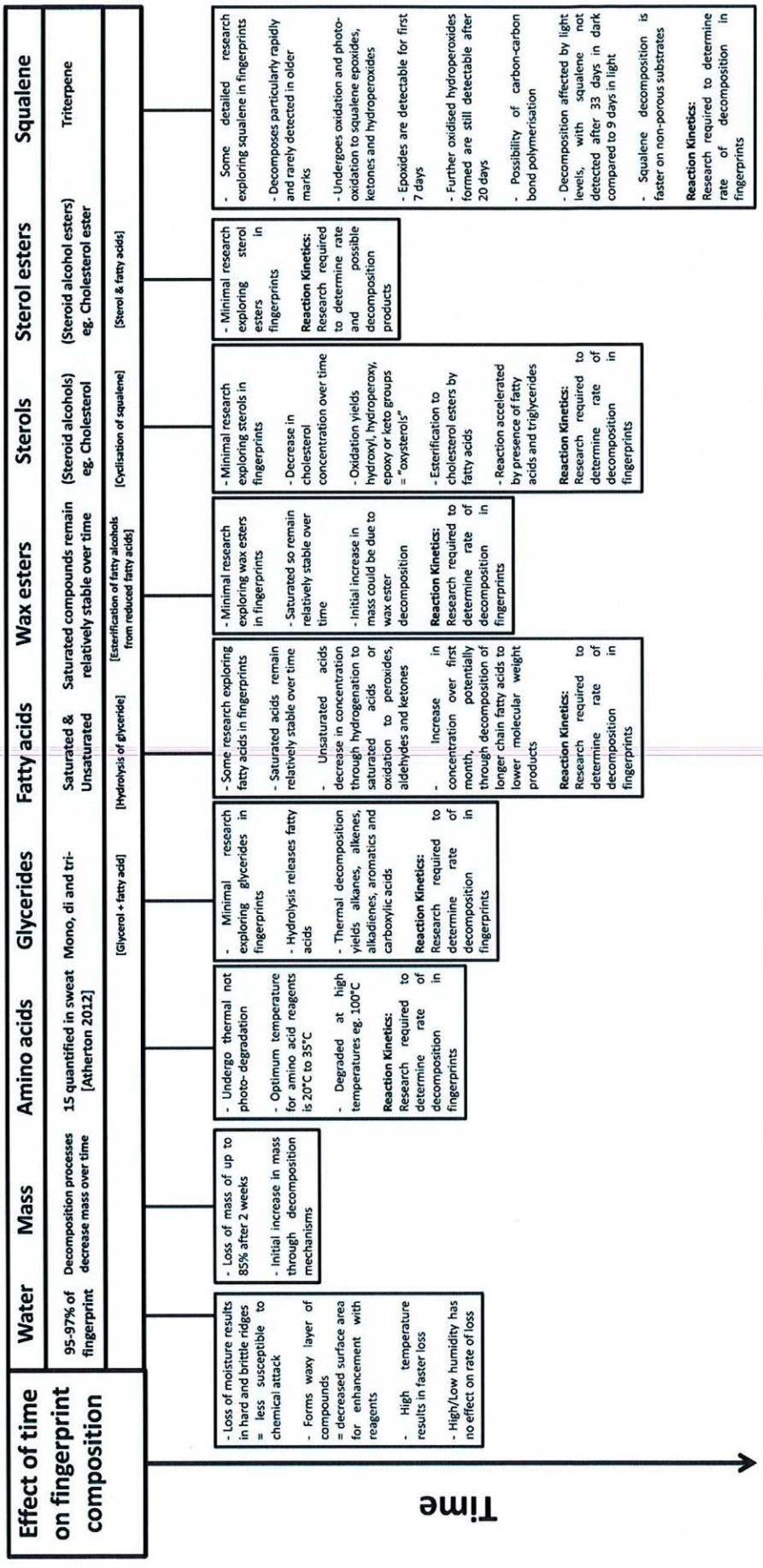

Fig. 10. Summary of effect of time on composition of latent marks.

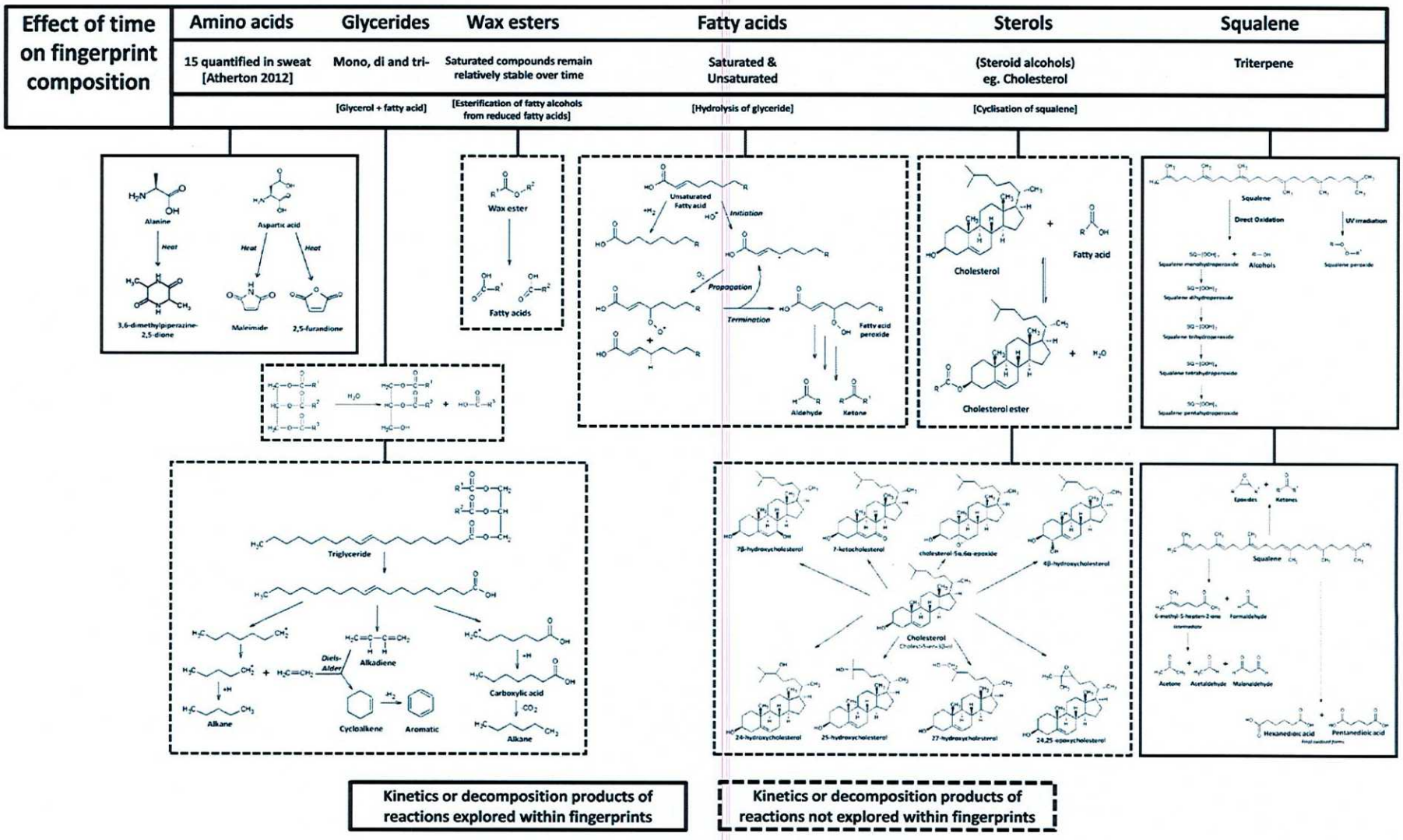

Fig. 11. Summary schematic of possible decomposition processes for compounds present in latent marks.

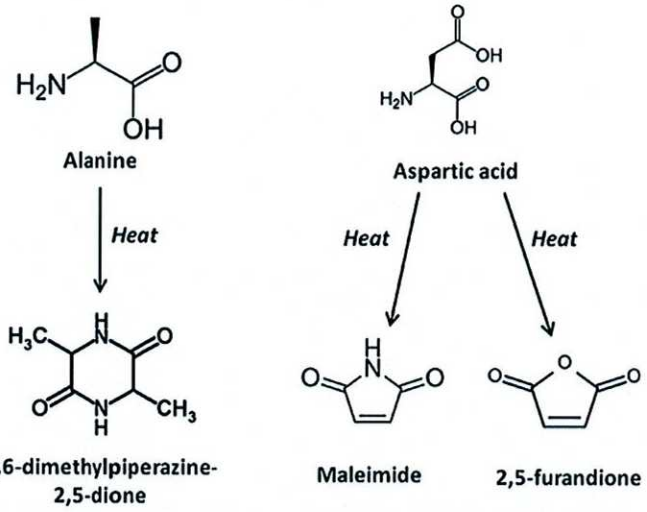

Fig. 12. Decomposition of alanine and aspartic acid under heat.

rate of water loss is not dependent on the relative humidity [85,90]. More research has explored the effect of humidity on enhancement. Research exploring amino acid reagents showed that DFO is less affected by humidity compared to ninhydrin or indanedione, as exposure to high humidity for 1 h did not affect the quality of the enhancement [93,114,115]. This may be due to the general sensitivity of the enhancement methods and the effect of humidity on porous substrates, rather than due to variations in composition or physical characteristics of the fingerprint. Other enhancement techniques are affected by humidity. The quality of fingerprints enhanced with silver nitrate is adversely affected by high humidity levels [93]. Cyanoacrylate fuming quality also varies with humidity, with eccrine constituents most influenced by humidity changes [114], as sodium chloride salt crystals absorb water into the fingerprint ridges at higher humidity [114]. Further research is needed to explore the effect of humidity on fingerprint composition so as to fully understand how composition changes over time [13].

4.3. Vacuum

Fingerprint enhancement can use vacuum or reduced pressure chamber methods, such as VMD. Fingerprint chemistry can also be explored using vacuum based methods, such as SIMS and MALDI [116]. It is important to identify the effect reduced or vacuum pressure can have on fingerprint composition, as changes in composition may affect the efficacy of subsequent enhancement [116].

One study identified a decrease in fingerprint mass when subjected to low pressure vacuum chambers, predominantly due to a reduction in water, as well as several fatty acids, fatty acid esters and squalene [117]. The mass lost was determined to be equivalent to 26% of the mass of the fingerprint, which the study concluded was equal to the equivalent of aging the fingerprint for approximately 5 weeks under ambient conditions [116]. One study identified fingerprints aged over 1 week showed reduced concentrations of the saturated C12 fatty acid, the unsaturated *trans*-C18 fatty acid and squalene under natural conditions [116]. Marks placed within the vacuum chamber, had significantly reduced relative concentrations of the saturated C14 and C15 fatty acids, indicating that vacuum conditions result in reduced concentrations of compounds that are still present under natural conditions after aging for 1 week [116].

This study shows exposure to vacuum pressure can significantly affect fingerprint composition. This is particularly relevant for enhancement techniques, such as iodine fuming, solvent black 3, basic violet 3 immersions and small particle reagents, which target the constituents most readily lost under vacuum conditions [78,116,118]. These changes to composition may result in a decrease in the quality of the enhancement if the fingerprint has been previously subjected to a vacuum system [116].

4.4. Other variables

Research has identified composition is also affected by other factors, such as air circulation, atmospheric contamination, condensation, dust, friction (handling or other natural movement), precipitation and ultraviolet and other radiation [14,34]. Minimal research has explored these variables in any depth, although they are generally accepted as of significance in composition studies [26]. Research into the effect of these various environmental variables on fingerprint composition is clearly required, so as to identify the changes that occur, as well as the respective rates.

5. Age determination

Determining the age of a fingerprint is a relatively unexplored area of fingerprint research. A successful method, with reliable and reproducible age estimates, would have numerous potential advantages for criminal investigations, as well as data privacy. There are currently no accepted analytical methods, although several methods have been previously proposed. These have predominantly focused on physical and chemical changes to fingerprints over time and their effect on subsequent enhancement with powders or chemical techniques. These previous methods are detailed in the following sections, as well as a discussion of the characteristics required for an optimum method, based on quantitative kinetic changes to fingerprint composition over time.

5.1. Previously proposed methods

Several different research groups have explored changes to fingerprints over time [13–15,20,33,34,58,73,74,88,93,95–98,108,119–126],and numerous attempts have been made to determine an accurate method for determining the age of a fingerprint. Some of the methods first proposed are particularly unreliable however, as they focused purely on changes to physical characteristics over time [127]. Research has predominantly focused on four main areas: the success of powdering methods, changes in fluorescence wavelengths and intensity, changes in ridge features, and electrical methods exploring the decay of electrostatic charge.

5.1.1. Powdering & enhancement methods

One proposed method explored the success of ridge detail development using powder, with the age estimation based on how well the powder adheres to the ridges, or the overall clarity of the enhanced ridge detail [34]. One key study explored fingerprints deposited on aluminium drinks cans against a crime scene fingerprint recovered using magnetic powder [128]. Fingerprints contaminated with different ratios of 'relevant contaminants' [34] were deposited on a number of test cans and aged in an attempt to replicate the crime scene conditions [34]. The experimental setup followed the premise that the original enhanced fingerprint obtained was composed of either natural perspiration or food contaminants recently handled by the subject and thereby, failed to recognise other constituents within the fingerprint, as well as the possibility of variations to those compounds over time [129]. The experiment ignored entirely possible differences to fingerprint composition between donors and its subsequent changes over time, the viscosity of the fingerprint, and the quantity of the residue, without which, it would not be possible to determine the evaporative rate of the fingerprint [129]. It was stated in court that the crime scene fingerprint was between 24 and 48 h old [130], although this conclusion was regarded as highly unreliable as the composition of the fingerprint was only 'partially recognised' [129].

One early study used enhancement success to explore the effect of temperature and humidity on fingerprints [127]. Fingerprints were deposited on glass substrates and aged at varying humidity (32%–98%) and temperature (20–30 °C) for seven weeks, and enhanced across the aging time [42]. The study determined humidity had the greatest effect on the quality of enhancement, with high humidity producing the lowest quality of enhanced ridge detail [42]. The temperature range explored was reported to have no effect on enhancement success, indicating that loss of moisture was not a significant factor in the enhancement process [127]. No conclusions identifying fingerprint age were obtained however. A subsequent study explored the effect of environmental variables on fingerprints deposited on a glass window over time [131]. The fingerprints were exposed to heat, cold, humidity and dust and were enhanced with powder and lifted for comparison over three days and after three months [42]. Comparison of the quality of the enhanced fingerprints determined no differences, either visually or microscopically, for any of the ages of fingerprints recovered [131], demonstrating the unreliability of attempting to determine fingerprint age purely on visual differences or the success of enhancement. Environmental variables were also explored in an extensive study using a database of 20,000 fingerprints enhanced using powders from numerous substrates under a selection of environmental conditions [132]. The age of recovered fingerprints was determined through comparison to the database and identifying specific characteristic properties within the ridge detail that were observed to change over time. Although this method identified the importance of exploring the effect of environmental and substrate variables, this method still relies on physical enhancement success and does not take into account fingerprint composition, or possible variations between donors.

A recent study explored fingerprint degradation through exposure to specific monitored laboratory conditions [37]. A number of variables were explored, including temperature, humidity, air currents, light levels and different substrates over 6 months, as well as the difference between eccrine and sebaceous fingerprints [37]. The aged fingerprints were enhanced using a titanium dioxide-based powder and results indicated that fingerprints degraded similarly in both light and dark conditions, with sebaceous marks on glass being the most reliable for identification after a longer aging period [37]. Age estimations for the recovered fingerprints were not proposed however, as enhancement using powders is particularly inaccurate, as many previous studies have determined [42,127].

Some research has explored the effect of time and environmental variables on other enhancement methods. One study explored the effect of water on fingerprints on porous substrates, as a potential method for determining the age of a fingerprint. Fingerprints of different ages were immersed in water prior to chemical enhancement using solvent black 3 [133]. The fingerprint age had little effect on enhancement success however, with only the length of submersion and the resilience of the substrate to moisture being the determining factors [133]. This is not that unexpected, as solvent black 3 targets sebaceous fats within a fingerprint [9], which are less subject to change over time.

The clarity of an enhanced aged fingerprint is the result of the original quality of the mark, rather than the result of changes over time [120,127,134]. It has been clearly shown that using the intensity of a successful enhancement as a guide for age estimation is an unreliable approach, as a fingerprint can "last for weeks at rather extreme conditions and still be easily detectable" [127]. Additionally, this study and several others, report the unreliability of attempting to ascertain age from a microscopic examination, due to the lack of any age dependent processes that affect enhancement, particularly using powders [127,135].

5.1.2. Fluorescence

An alternative method explored the red-shift change in fluorescence wavelength from fingerprints over time. Studies have identified recently deposited fingerprints exhibit green or yellow fluorescence compared to orange fluorescence in older fingerprints [122,124]. Although using the degree of red-shift indicated a potentially quantitative way of determining the age of fingerprints, findings showed variations between donors and over time were too large to allow for accurate age estimations [124]. A recent study was successful in estimating fingerprint age through repeated measurements over several days to obtain multiple measurements for an aging curve [136]. Age estimations were possible up to three weeks after deposition, with a median uncertainty of 1.9 days. The major drawback from this study however, was the inability to estimate ages for every fingerprint. 77% of female and 27% of male fingerprints displayed insufficient fluorescence to attempt the method and of those with sufficient fluorescence, only 55% of those met the criteria for age estimations [136]. Additionally no age estimations were possible for female donors, which the study attributes to the 'lower excretion of skin components by women' [136]. One possible advantage of this method however, is that it accounts for substrate effects due to the repeated measurements over several days.

Early research exploring fluorescence to determine fingerprint age was deemed unreliable [42] predominantly because it failed to take into account variations in composition between donors and over time on the fluorescence produced. Repeated measurements over several days to were used to overcome this variation [136], although this method does not take into account the presence of contaminants. Contaminants are frequently present in fingerprints and can dominate the fluorescence produced. Relying on the intensity of the fluorescence or the red-shift of natural constituents alone is unlikely to provide a reliable method for age determination.

One possible approach could be to explore the fluorescence produced by specific compounds and their subsequent degradation through oxidation at known wavelengths, superficially explored by [136]. A ratio of fluorescence from several compounds could be used as a more reliable method for age determination, as this would allow for a single measurement to be taken, as opposed to repeated measurements over several days. Significant further research is therefore required to minimise the potential errors to age estimations due to contaminants, variations in fingerprint composition, as well as the effect of environmental variables affecting the rate of oxidation.

5.1.3. Changes in ridge features

Some research has explored the effect of time on ridge features as a potential age determination method. One very basic method used the rate of healing of a wound on a finger compared to the impression in a deposited fingerprint [137], although this has very obvious limitations for real world applications. A number of studies have explored the degeneration of ridge features and width, with a particular focus on changes to individual pores over time [138,139]. One study identified a decrease in ridge width over 180 days. Indoor conditions showed a decrease from 0.32 mm to 0.26 mm and from 0.30 mm to 0.24 mm for fingerprints aged outdoors [139]. However there were significant overlaps between aged fingerprints, reducing the reliability of the method. Donor blood type was also identified as an influencing factor, as the rate of degradation of both DNA and epithelial cells decreased through blood groups O, A, AB and B [139]. This effect has not been identified in any other study and the exact implications are not fully understood.

Recent research has used technological advances to observe changes to ridge patterns with time on a hard drive platter [38]. Research has used a high-resolution non-invasive chromatic white light optical sensor [39,40] combined with pattern-recognition techniques to determine an aging curve [39,138]. Scanned fingerprints were separated into two categories based on the quality of the ridge detail – younger or older than 4 days [39]. The average error of approximation was determined to be between 13% and 40% [41], indicating further research is required to establish the overall reliability of the method [138], as well as the applicability of the method on real-world substrates.

Recent research has determined a method for age determination using physical characteristics is less viable, as ridge detail is highly

dependent on the original fingerprint [138]. An age determination method based on physical characteristics requires knowledge of the initial ridge width, pore size and distribution throughout the fingerprint [138], which is, in almost all circumstances, not possible. Therefore, although these approaches can provide age estimations, they are either focused on very limited scenarios or do not produce sufficiently reliable results to be successful as a reliable methodology for fingerprint age determination [40].

5.1.4. Electrical methods

An alternate methodology focuses on the electrical properties of a fingerprint, in terms of changes to electrostatic charge with time [140,141]. One proposed method relies on contact electrification, which studies suggest is independent of both the subject and the transfer method [142]. The decay of the fingerprint charge is thereby only affected by the physical properties of the material and the environmental conditions [142]. The study explored this decay over 14 days and determined image definition remains while the overall level of charge decreases with time [142]. The study found 'very old fingerprints were not visible using charge imaging' [142] and suggested that an estimation of age might be possible for recently deposited fingerprints. One possible option would be to obtain two measurements to produce an aging curve. However, this method is currently limited by very long scan times, a sample area of only 5 μm, and by the substrate; the study explored fingerprints deposited on thin insulators, such as polytetrafluoroethylene (PFTE) and acknowledges issues with thicker samples [142]. Further research to explore this method is clearly required, so as to investigate the charge decay rates on a range of different materials, as well as from different donors.

5.2. Characteristics of the optimum method

Previous research exploring age determination has identified wide variations in a fingerprint's ability to survive under a variety of environmental conditions [42]. A number of unreliable methods have been previously proposed, based on the rate or success of enhancement [42,127], or observations of changes to ridge detail over time. Research has suggested three ways to explore fingerprint age determination [34]: the physical appearance of the developed/undeveloped fingerprint, identifying the environmental factors over a given period of time, or the identification of changes in chemical constituents [34]. The first two methods suffer from the difficulty of reproducing the original conditions [142], meaning the third is considered to be the only viable method [34,42]. One possible approach is to explore how the concentrations of specific components within the fingerprint change over time, through various decomposition processes. The exploration of chemical changes over time is regarded as the most realistic method for developing an accurate and reliable method that will be universally accepted to determine the age of a fingerprint [34].

The initial composition at the point of deposition is a crucial factor, as it is the starting point of an aging curve [20]. Without this knowledge, it is difficult to make definitive conclusions regarding exact changes to composition [14,20]. Additionally, previous research discussed in Section 2 has demonstrated fingerprint composition can vary significantly between donors, as well as due to the effects of environmental variables [14,17,19,24,37]. However this can be overcome through exploration of the relative amounts of constituents and key compounds inherent to fingerprints. Identifying the subsequent decomposition products allows for the potential development of a reliable method [20]. A number of studies have explored the reaction kinetics of decomposition for several compounds within fingerprints [14,16,20,98], the relative amounts of which could be used to produce a method to determine the age of a fingerprint.

5.2.1. Potential compounds for fingerprint age determination

A number of studies have explored variations in lipid concentration over time [14,16], as discussed in Section 3.2. Research has determined unsaturated compounds, decrease more rapidly over time. Fatty acids reduce significantly in concentration over 30 days [74]. Minimal research has explored reaction kinetics, in terms of the rate of decomposition over time, although some decomposition products have been identified. Tetracosane was identified in samples of moderate age [16], as well as volatile lower molecular weight breakdown products [56]. The decomposition of oleic acid has been explored using MALDI-MSI and several epoxides, alcohols and aldehydes were identified [97]. Further research exploring other lipids is required, so as to fully investigate the decomposition and reaction kinetics under a number of different environmental variables.

Eccrine constituents could also be used for age estimations, as one study monitored leucine over 236 days and identified a decrease to approximately 55% of the original concentration [67]. Another study explored the effect of temperature on amino acids and determined higher temperatures result in reduced enhancement [143], possibly due to loss of material. This was supported by a more recent study that identified the optimum temperature range as 20 °C to 35 °C and stated that if a fingerprint were exposed to heat for prolonged periods of time, enhancement would be much more difficult [113]. Recent research determined amino acids undergo thermal degradation, as opposed to photo-degradation [110] and decomposition products for some amino acids have been identified. High temperature pyrolysis-GC–MS at 500 °C was used to identify 3,6-dimethylpiperazine-2,5-dione and maleimide as decomposition products of alanine and 2,5-furandione as the decomposition product of aspartic acid [61], as shown in Fig. 12. The same decomposition products have been identified in recent studies and have been proposed as a possible cause for fingerprint fluorescence after exposure to increased temperature [111,112]. Further research is needed to identify the kinetics of these decomposition reactions, if they are to be used for a reliable quantitative aging methodology.

Cholesterol could be a suitable target compound for fingerprint age determination, as it has been observed to decrease in concentration over time [20], indicating the presence of decomposition mechanisms. Research in other areas, as discussed in Section 3.3.4, has determined cholesterol can form multiple products through oxidation [103]. The identification of these products within a fingerprint with the rate at which they form could allow for an age estimation method.

Squalene has been explored in some detail within fingerprints and a number of decomposition products have been identified [14,16,20,74,108], as discussed in Section 3.3.5. The concentration of squalene decreases rapidly over time and is rarely detected in older fingerprints [14,98], making it a potentially useful target compound for age determination. The presence or absence of squalene epoxide could also be used for age estimation, as the concentration increases up to 5 days after deposition, but is undetectable after 7 days [98]. A range of hydroperoxides are also produced over time, including the main oxidation product squalene mono-hydroperoxide to squalene penta-hydroperoxide, through the di-, tri- and tetra-hydroperoxide versions [98], as shown in Fig. 9. Findings showed squalene tetra- and penta-hydroperoxides were still detectable after 20 days [98]. This is particularly useful for age estimations, as the concentrations of squalene, squalene epoxide and squalene hydroperoxides could all be compared. A recently deposited fingerprint would have greater concentrations of squalene, squalene epoxide and the mono-hydroperoxide form compared to an older fingerprint, which would have lower concentrations of squalene and the epoxide, and higher concentrations of several hydroperoxides. More research is required to explore squalene reaction kinetics in greater detail, as well as to determine the effects of substrate interactions and environmental variables, so as to establish a reliable methodology for determining the age of a fingerprint.

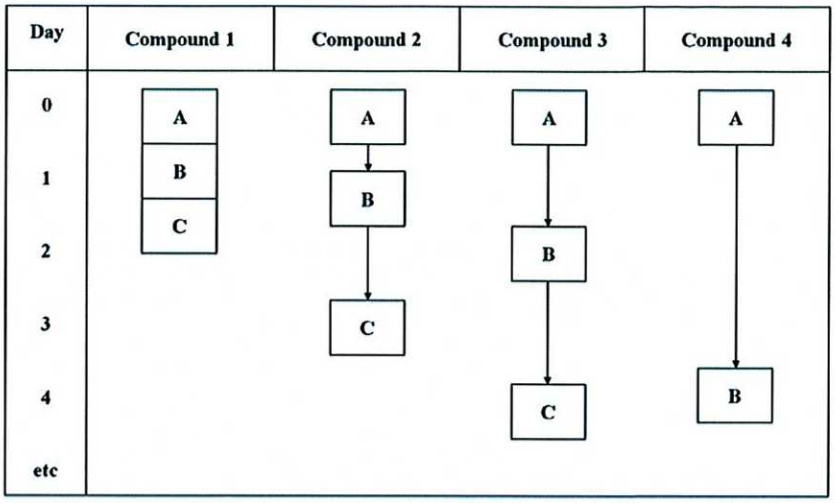

Fig. 13. Graphical representation of proposed aging method with 4 compounds with different rates of decomposition.

5.2.2. Points to consider

We propose the optimum method for age determination is likely to involve monitoring changes to the composition of a fingerprint over time, through the exploration of key constituents within the recovered fingerprint. Detailed knowledge of the precise reaction rates of various decomposition mechanisms, would allow for the concentrations of starting parent compounds to be compared to those of the decomposed products. Knowledge of several rates from decomposition mechanisms would increase the reliability of the method, as the parent to product ratio could be determined for several different decomposition mechanisms within the fingerprint eg. squalene, cholesterol, fatty acids. The age estimation would be based on the concentrations of several different chemical species detectable within the fingerprint, as shown graphically in Fig. 13, all with different decomposition rates and affected differently by environmental variables. This would yield a significantly more accurate method than a focus on the degradation of a single chemical species. The decomposition mechanisms explored would need to be predominantly driven by exposure to oxygen, with minimal variations in decomposition rates through exposure to UV radiation or fluctuations in temperature; alternate mechanisms would be too inconsistent to establish a reliable methodology.

The effect of environmental variables and substrate characteristics on the rate of decomposition for all the compounds of interest would need to be thoroughly explored. A statistical model could then be developed to determine fingerprint age based on known environmental factors, such as an approximate temperature range, or duration of light exposure. Using this model, an age or age range could be provided, based on the concentrations of specific constituents within the fingerprint. The model would also allow for the use of statistical probability to quantitatively estimate fingerprint age to a certain confidence level, as the estimate would be based on known and reproducible decomposition mechanisms of specific key compounds.

Current analytical methods often require preparatory steps, such as derivatisation for mass spectrometry and are destructive. For the proposed optimum method to be implemented into current practices, it would be necessary to identify a non-contact quantitative analytical method, which could non-destructively determine the concentrations of specific compounds within a fingerprint. The ridge detail of the recovered fingerprint would then be preserved for comparison against suspect fingerprints.

One limiting factor with this method is the use of enhancement reagents which target specific constituents within the fingerprint, thereby altering the composition. This composition change would need to be determined, although the best approach would be to identify compounds that are unaffected by the various enhancement processes currently in use. This would allow the proposed methodology to be reliably applied after all required enhancement procedures.

6. Conclusion

Fingerprint research has been carried out for many years, but there remain significant gaps in scientific knowledge. Future advances should therefore remain a priority. The exploration of the effect of time on composition is one such gap. Further research allows for the exploration of new and novel enhancement reagents targeting previously unknown compounds within a fingerprint, as well as potential improvements to existing methods and formulations through a greater understanding of reaction mechanisms. Donor characteristics could also be determined, which would greatly benefit intelligence gathering. Current findings can determine donor characteristics, such as the gender of the individual [19], race characteristics [24] and donor age [17]. This suggests the eventual possibility of profiling an offender, purely from the chemical content of a recovered fingerprint.

Intelligence gathering would also benefit from the knowledge of when the fingerprint was deposited. There is no currently accepted method for determining the age of a fingerprint. Previous research, as summarised in Table 6, has so far failed to identify a method that is sufficiently reliable and accurate across the wide range of variables commonly encountered. One possible approach is to explore the effect of time on fingerprint composition. This review proposes identifying specific components and their rates of reaction for decomposition mechanisms. Identification of the degree of decomposition present in a recovered fingerprint would allow for age estimation. Decomposition mechanisms that are driven by oxygen exposure would be advantageous, so as to reduce the variability in age estimation due to the effect of other environmental variables.

Naturally considerable research is still required, but we believe this method has merit as a way to quantitatively determine the age of a fingerprint across a range of substrates, as the flexibility of the methodology could accommodate such a complex set of variables.

7. Future perspectives

As discussed, further research exploring fingerprint composition is necessary to advance both understanding and the role of fingerprints in criminal investigations, as well as to potentially develop a reliable age determination methodology. The following sections discuss 7 key areas identified as in need of further research and discuss potential future developments.

Table 6
Summary of previously explored aging methods with proposed best approach methodology.

Aging methods	Previous methods				Optimum method
	Powdering & enhancement methods	Fluorescence	Changes in ridge features	Electrical methods	Analysis of composition
Description	Degree of success of development of ridge detail using powder	Exploration of repeated measurements and red-shift change over time	Observation of changes through degradation to ridge features using optical sensors	Observation of electrostatic charge and decay remaining on surface after deposition	Exploration of chemical changes to fingerprints over time through comparison of parent compounds and degradation products
Advantages	Simple observations of degree of success of enhancement	Potentially quantitative, non-destructive method	Simple observation of ridges to estimate age, non-destructive	Independent of subject and transfer method	Qualitative and quantitative, reproducible, potentially non-destructive if method identified
Disadvantages	Unreliable – no account for variations in composition between donors, presence of contaminants, or changes to composition over time	Unreliable – no account for variations in composition between donors, changes over time or fluorescent contaminants	Unreliable – large average errors with preliminary results, no account for variations in composition between donors or over time	Minimal research carried out and limitations of technique not yet known	Relatively unexplored – large amount of research required to determine effect of substrates. Potentially destructive method required for quantitative analysis
Further research	Unlikely due to unreliability of method and numerous studies identifying major unreliability in the method	Exploration of fluorescence ratios of key compounds within fingerprints	Exploration of changes on range of substrates with large scale tests required	Exploration of decay on range of substrates with large scale tests required	Exploration of decay on range of substrates with large scale tests required, as well as the effect of enhancement reagents on fingerprint chemistry

7.1. Key areas to explore

For the identification of donor characteristics from composition and for the exploration of compositional change over time to be a viable aging method, there are several key areas that need to be fully explored:

1) Identification of decomposition products

To fully understand the chemistry of fingerprints, the reactions and mechanisms that occur over time need to be determined, as well as all the possible reaction intermediates and final end products.

2) Determination of the reaction kinetics

The kinetics of the chemical breakdown reactions for the identified compounds and their intermediates need to be determined. From this, several compounds can be selected which have sufficiently different decomposition rates, so as to identify the fingerprint composition at specific time intervals after deposition.

3) Determination of compound ratios

Specific compounds and their decomposition products can be used to produce reagent-product ratios. The effect of time on these ratios can then be explored, which will allow for more accurate age estimations, compared to concentration changes of single compounds alone.

4) Determination of the effect of environmental variables and substrates

Fingerprint chemistry is affected by a multitude of variables, which affects the decomposition kinetics. Exactly what these effects are needs to be determined, so as to identify how composition is affected and to further develop an accurate model for age estimations.

5) Determination of the effect of chemical enhancement

To explore donor characteristics and age estimations in a real-world application requires the exploration of fingerprint composition after chemical enhancement. The effect of individual and numerous sequentially performed enhancement processes needs to be explored, so as to identify changes to fingerprint chemistry. This allows for improvements to be made to age estimations, as the model can be additionally developed to include the effect of enhancement.

6) Large scale tests to explore significance of findings

Lastly large scale blind tests and operational trials are required, so as to fully explore the relationship between composition and donor traits, and to test the model for determining fingerprint age. In both cases it is important to determine the significance of an identified trend, as well as identify the accuracy, precision and reliability of the proposed method for determining the age of a fingerprint.

7.2. Potential future developments

One possible benefit to increased knowledge of fingerprint composition and the changes that occur with time is the development of novel enhancement reagents, which could be specifically tailored for determining fingerprint age. This could occur in two ways. Firstly, an enhancement reagent could only target fingerprints of a specific age, through selective chemical reaction with compounds that are only present for a known duration and then rapidly decompose. Selective enhancement using squalene or squalene epoxide as the target compound could be explored, as both are detectable in freshly deposited fingerprints but decrease in concentration over time, with squalene epoxide undetectable in latent marks after 7 days. This would allow an enhancement reagent to selectively develop fingerprints relevant to when a crime was committed. One example of this could be a shop burglary, which occurred at a known time and where potential surfaces regularly receive a large volume of deposits. Successfully distinguishing recent from older background fingerprints would be of significant benefit, as it would reduce the volume of evidence requiring processing and result in faster intelligence for suspect identification.

Secondly, an enhancement reagent, or multi-step enhancement process, with the ability to selectively enhance numerous compounds could be used. As specific composition changes with age, this could be used to develop a reagent that reacts with several different components present in the fingerprint at different times to form different coloured complexes. This would allow for immediate assessment of the fingerprint age, purely based on the colour of the enhanced fingerprint. Squalene hydroperoxides could be potentially used, as they are potential receptors for chemi-luminescent development techniques and are present

in different concentrations over time, as discussed in Section 3.3.5. Potential reactions with contaminants would naturally need to be investigated to reduce the possibility of incorrect age determination, although a highly selective chemical method would reduce the possibility of false colour enhancement occurring.

Currently both of these methods remain unexplored, but the identification of potential benefits to enhancement through increased fingerprint knowledge clearly highlights the requirement for further research. Until a methodology for age determination has been fully explored and is routinely used in investigations however, attempts to determine the age of a fingerprint should be explored with care, so as to prevent damage to the credibility of an examiner or the use of fingerprints as evidence in criminal investigations generally.

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No. 126383

IN THE

SUPREME COURT OF ILLINOIS

PEOPLE OF THE STATE OF ILLINOIS, Plaintiff-Appellant, -vs- JOHN CLINE, Defendant-Appellee.	)	Appeal from the Appellate Court of Illinois, No. 1-17-2631. There on appeal from the Circuit Court of Cook County, Illinois , No. 15 CR 18158. Honorable Vincent M. Gaughan, Judge Presiding.

NOTICE AND PROOF OF SERVICE

Mr. Kwame Raoul, Attorney General, 100 W. Randolph St., 12th Floor, Chicago, IL 60601, eserve.criminalappeals@ilag.gov;

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Under penalties as provided by law pursuant to Section 1-109 of the Code of Civil Procedure, the undersigned certifies that the statements set forth in this instrument are true and correct. On October 12, 2021, the Brief and Argument was filed with the Clerk of the Supreme Court of Illinois using the court's electronic filing system in the above-entitled cause. Upon acceptance of the filing from this Court, persons named above with identified email addresses will be served using the court's electronic filing system and one copy is being mailed to the defendant-appellee in an envelope deposited in a U.S. mail box in Chicago, Illinois, with proper postage prepaid. Additionally, upon its acceptance by the court's electronic filing system, the undersigned will send 13 copies of the Brief and Argument to the Clerk of the above Court.

/s/Carol M. Chatman
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