



Analysis and implications of the miscarriages of justice of Amanda Knox and Raffaele Sollecito



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ABSTRACT

The case of the ‘murder of Meredith Kercher’ has been the subject of intense media scrutiny since 2007 when the offence was committed. Three individuals were arrested and accused of the crime. Amanda Knox and Raffaele Sollecito were exonerated in March 2015. Another defendant, Rudy Guede, remains convicted as the sole perpetrator. He was implicated by multiple DNA profiles recovered from the murder room and the bathroom. However, the evidence against Guede contrasted strongly with the limited evidence against two co-defendants, Amanda Knox and Raffaele Sollecito. There were no DNA profiles pertaining to Amanda Knox in the murder room itself. She was separately implicated by a knife recovered remote from the crime scene (discovered in a cutlery drawer at Sollecito’s apartment), along with DNA profiles in a bathroom that she had shared with the victim. Upon analysis a low level trace of DNA attributed to the murder victim was found on the blade of a knife, along with DNA profiles attributed to Amanda Knox from the handle. However, there was no evidence of blood on the knife blade itself. A separate key piece of evidence was a DNA profile attributed to Raffaele Sollecito recovered from a forcibly removed bra-clasp found in the murder room. There followed an extraordinary series of trials and retrials where the pair were convicted, exonerated, re-convicted and finally, in March 2015 they were finally exonerated (no further appeal is possible). Since Knox and Sollecito have been found innocent it is opportune to carry out an extensive review of the case to discover the errors that led to conviction so that similar mistakes do not occur in the future. It is accepted that the DNA profiles attributed to them were transferred by methods unrelated to the crime event itself. There is a wealth of material available from the judgements and other reports which can be analysed in order to show the errors of thinking. The final judgement of the case—the Marasca-Bruno motivation report—exposes the illogicality of much of the previous court proceedings that led to the convictions and provides useful guidance for judges to follow.

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1. Introduction

The controversial case of ‘Death of Meredith Kercher’ was discussed in Rome on April 27th–28th, 2012, at an international conference organized by Vince Pascali. The meeting was entitled ‘The hidden side of DNA profiles’[1]. At the time of the meeting, Amanda Knox and Raffaele Sollecito had already been convicted at trial, and subsequently exonerated at appeal. It had appeared to the group assembled in Rome that a miscarriage of justice had already occurred and it was discussed as such. Surprisingly, the judgment was set aside a year later by the ‘Supreme Court of Cassation’ and a retrial was ordered. Knox and Sollecito were convicted again at another hearing presided over by Judge Nencini. It wasn’t until the final appeal (the Marasca-Bruno motivation) was heard in 2015,

that the pair were exonerated and a miscarriage of justice (with certainty of binding finality) was officially confirmed.

Miscarriages of justice represent a failure of the criminal justice system. When they occur, they deserve full attention and analysis in order to establish ‘what went wrong’. It is of little use to simply consign such events to history, dismissed as a ‘one-off’ event, since history does tend to repeat itself. A period of reflection should follow at all levels of the criminal justice system in order to answer questions such as:

1. Can we identify the flawed practice that led to the wrongful convictions?
2. What can be done to prevent reoccurrence in the future?
3. How can the interaction of scientists, investigators and judges be improved?
4. Are there any other cases, already prosecuted, that are similarly affected.

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It is likely that for every miscarriage that has been identified, there are many that are never discovered because errors tend to be serially repeated across different cases [2]. Once a flawed method has been established as 'normal practice', practitioners perceive their reports to be scientifically acceptable and court-acceptance unwittingly raises the credibility to become an established practice via a positive feedback loop. This strengthens the practitioners' confidence, further reinforcement continues via peer review and training i.e. the failure is manifest (and self-perpetuated) at all levels of the criminal justice system. The consequences can be devastating. A recent example was exposed in relation to hair analysis conducted by FBI laboratories[3] where: "Twenty-six of 28 FBI agent/analysts provided either testimony with erroneous statements or submitted laboratory reports with erroneous statements." And this has resulted in numerous¹ wrongful convictions in the USA.

The case discussed here relates to the proven miscarriage of justice of Amanda Knox and Raffaele Sollecito in relation to the accusation of murder of Meredith Kercher in Perugia, Italy on the 1st November, 2007². Another defendant, Rudy Guede, was separately tried and found guilty of her murder in October 2008. In contrast with Knox and Sollecito, the evidence against Guede was overwhelming. His DNA was found at numerous sites at the crime-scene, including the victim's vaginal swab, and her clothing. Furthermore, he had no legitimate access to the premises. However, he later implicated Knox and Sollecito after initially denying their involvement in the crime.

Knox and Sollecito were tried in January 2009 before Judge Giancarlo Massei. They were found guilty and sentenced to 26 years and 25 years imprisonment, respectively. Under Italian law convicted defendants are guaranteed a retrial and this began in November 2010 before Judges Hellmann and Zanetti. In October 2011, these judges acquitted Knox and Sollecito, accepting defence arguments on the lack of evidence and contamination. Both defendants were released. There followed a successful appeal from the prosecution (the Galati-Costagliola appeal) and in March 2013, the 'Supreme Court of Cassation,' presided over by Dr Severo Chieffi, set aside the judgment of the appellate court and ordered a retrial at the appeal level. In January 2014, an appellate court panel led by Judge Alessandro Nencini found the pair guilty (again), overturning the previous Hellmann-Zanetti judgement. Finally the pair were acquitted by the Marasca-Bruno motivation report and this ended the judicial process under Italian law.

This paper is necessarily restricted to the interpretation of the DNA evidence—without it the original convictions probably would not have occurred. Independent analyses of the data have been undertaken by Gill [2] and Balding et al. [4]. Given the proven innocence of Knox/Sollecito we are confronted with multiple instances of the CSI effect, where prosecutors, scientists and judges, allow speculation to override logical thought processes. Unfortunately this is characteristic of miscarriages of justice (as an analogy see the excellent report of Vincent [5] relating to the miscarriage of justice of Farah Jama resulting from a contamination incident).

1.1. Hierarchy of propositions

It is well established that the preferred method to evaluate evidence begins with an understanding of the 'hierarchy of propositions framework' e.g. [6,7]. The lowest level of the

framework is the 'sub-source' level where the strength of evidence of the DNA profile is either described by a probability or a verbal statement. For low template LT-DNA profiles, it is often not possible to associate the DNA profile with a given body fluid such as blood or semen. This level of interpretation (e.g. the DNA came from blood) is described as the 'source-level'. However, courts are primarily interested in the 'activity-level' i.e. the method by which the DNA was transferred to the evidence. Mistakes arise if there is an attempt to directly associate the probability of the DNA profile (sub-source) with the 'activity', such as stabbing a victim. The statistics cannot be transposed in this way [8], yet this error of logic is often made. To evaluate evidence at the 'activity-level' requires a detailed understanding of transfer and persistence of DNA [9–12], as well as an understanding of the risks of potential contamination [13–19]. When such data are available, using the likelihood ratio method, the strength of evidence at the activity level is usually very much lower in comparison with the sub-source DNA profile [20], reflecting the inherent uncertainties.

1.2. Confusion of the 'identity' of the DNA profile with the 'activity' of its transfer

Gill [2] recently proposed a revised definition of the term "Trace DNA" that does not require LT-DNA as an anchor. Trace DNA is defined as any sample where there is uncertainty that it may be associated with the crime event itself—so that it is possible that the transfer may have occurred before the crime event (innocent transfer) or after the crime event (investigator mediated).

To avoid confusion of the 'identity' of the profile and the 'activity' whereby the DNA profile was transferred (to become evidence), it is necessary to consider two separate questions:

- Does the evidence support a 'match' with the defendant?
- How was the evidence propagated?

The analysis of the DNA profile only answers the first question, and cannot be used to adduce the strength of evidence that relates to the second part. In relation to the latter, a consideration of possible alternative modes of DNA transfer is as follows:

- Primary transfer (direct contact with an object or person).
- Secondary transfer (indirect or 'innocent contact', that is not related to the crime itself).
- Laboratory contamination.

In this case Sollecito, Knox and Kercher all lived in close proximity, hence it was not surprising to find their DNA profiles at the crime-scene, forming part of the pre-existing background. Consequently, the 'identity' of the DNA profiles was always a secondary consideration to the *modus operandi* of transfer possibilities listed above.

2. List of the judgements and access to the key documents (English translations)

The key reports are listed chronologically:

December 2009 (published March 2010): The Massei sentencing report [21] (the judges reasoning for the original conviction).

June 2011: Conti-Vecchiotti Report [22] (a report by the defence experts appointed by the Hellmann-Zanetti court).

October 2011 (published December 2011): The Hellmann-Zanetti motivation report [23] (the judges reasoning for the acquittal of Knox and Sollecito).

February 2012: The Galati-Costagliola appeal [24] (the prosecution argument against the acquittal).

¹ Seventy four out of 329 wrongful convictions overturned by DNA evidence involved faulty hair analysis.

² Although the time of death was never conclusively established, most sources pinpoint late evening of November 1st.

March 2013 (published July 2013): The Supreme Court of Cassation motivation report [25] (judges overturn the acquittal and a retrial is ordered).

January 2014 (published April 2014): The Nencini motivation report [26] (The conviction is upheld and the Hellmann report is rejected).

March 2015 (published September 2015): Marasca-Bruno motivation report v1.2 [27]. Acquittal of Amanda Knox and Raffaele Sollecito. The report highlights failures at all levels of the criminal justice system.

3. An outline of the case-circumstances

The victim, Meredith Kercher shared an upper-floor flat with Amanda Knox (their rooms were adjacent) and two Italian women in their late twenties. Four young men rented the flat below. Raffaele Sollecito was the boyfriend of Amanda Knox—she had started a relationship with him one week earlier.

The version of events put forward by the defence (now accepted as true) are as follows: on the morning of the 2th November, Knox returned home from Sollecito's apartment to shower and to change clothes. In the bathroom were small spots of blood in the sink; Kercher's bedroom door was locked. Knox returned to Sollecito's apartment to ask him to 'check things out' as she was naturally concerned. Sollecito unsuccessfully attempted to force entry into Meredith's bedroom (grasping the outer-door-handles). The police were called, and eventually the door into Meredith's bedroom was forced open³ and Meredith's body was discovered. She had been brutally stabbed in the neck and torso and had died from blood loss and asphyxiation. The cottage became a crime-scene. Rudy Guede was (and remains) convicted of the murder of Kercher by overwhelming evidence⁴. However, he was relevant to the prosecution case against Knox and Sollecito since, after initially denying their involvement, he alleged that he had acted together with them. The 'trace-DNA' evidence that was used in the trial of Amanda Knox and Raffaele Sollecito formed a major part of the evidence against them. However, there was no plausible motive⁵ for the attack.

A murder weapon had not been discovered at or near the crime scene, therefore the weapon must have been removed. A large knife (item 36) was later retrieved remote from the crime-scene in a cutlery drawer in Sollecito's apartment. The investigators alleged this to be the murder weapon. The defence said that it was not the murder weapon. The knife was tested for DNA and a profile matching Amanda Knox was found on the handle and a low-level profile matching Meredith Kercher was found on the blade. The prosecution alleged that the DNA was transferred to the handle when Knox stabbed Kercher with the knife—the DNA from Kercher was consequently transferred to the blade as a direct result of her bleeding from the wounds inflicted.

4. The evidence

4.1. The kitchen knife—collection and examination

The knife was collected from Sollecito's apartment on November 6, 2007. Officers testified that they wore ordinary clothes, but put on gloves and footwear before entering the unit. The knife was found in a kitchen drawer with other cutlery. It is not clear who handled the knife at the apartment, or whether the officers changed gloves between the handling of different pieces of evidence. Officers testified that the knife was put in an envelope, which had been used to store new gloves for the officers, for transfer to the police station. One officer who handled the knife at police headquarters had been in Kercher's apartment, and specifically in Knox's room, earlier in the day. Police officers did not remove other knives or test them to control for background contamination.

According to the report authored by the independent experts, Professors Carla Vecchiotti and Stefano Conti, one officer testified that, at the police station, he had noticed that the knife packaging was not properly sealed and that he closed two gaps in the envelope with tape. Another officer testified that, wearing gloves, he later removed the knife from the envelope and put it in a non-sterile box that he closed with tape.

The knife was transferred to the laboratory, where the item was examined. The laboratory reports showed that seven samples were taken from the knife (sample 36): four from the blade (samples B, C, E, and G) and three from the handle (A, D, and F). The knife was tested as one item in the middle of a course of 50 or 60 samples attributed to the victim; it was allegedly tested approximately seven days after the last testing of a sample belonging to Kercher. Anti-contamination procedures were not documented (or disclosed); it is unknown if or how surfaces were sterilized; what protective equipment was used; whether equipment was cleaned after each run; or how often technicians changed gloves. This was contrary to the European Network of Forensic Science Institutes (ENFSI) guidelines on contamination prevention [28] (for example) which state clearly: "There must be written procedures for cleaning and decontamination of facilities and equipment." In addition, "[r]ecords must be maintained" and "[e]nvironmental monitoring procedures should be written and records maintained." Even if all protocols had been scrupulously applied – a conclusion that was not supported by any disclosed document – there still remained the possibility that cross-transfer of DNA may have occurred. Specifically, this may involve transfer from a sample containing the victim's DNA to a laboratory surface, and thence to the knife. This was a possibility even if there are seven or more intervening days between examinations. Consequently it would have been prudent to test any evidence in separate laboratory facilities. At a minimum, samples of a potential murder weapon should be run *prior* to any known sample of the victim being analysed.

Comment: It is necessary to be pro-active to seek evidence that may "point away" from the defendants. The collection of other cutlery from the drawer could have been used as controls to determine the background of DNA profiles present on items not implicated as the crime-weapon.

4.2. Examination for the presence of blood on the knife

Tests on the knife, both on the handle and blade, conducted by court-appointed independent experts, Carla Vecchiotti and Stefano Conti, tested negative for blood using the highly-sensitive Tetramethylbenzidine (TMB) test.

³ Some of the flatmates kicked in the door while police were present.

⁴ Extract from the Massei report: "The hand-print found on a pillow in the room, on which the lifeless corpse of Meredith was found placed, turned out to have been made by Rudy Guede; the vaginal swab of the victim contained the DNA of the victim and of Rudy Guede (author's note: no sperm found); the DNA of Rudy Guede was also found on the cuff of Meredith's sweatshirt found in her room, and on a strap of the bra that she was wearing, found cut off and stained with blood; the DNA of Rudy Guede was also found on Meredith's purse, which was also in the room that she occupied. Further biological traces of Rudy Guede were found on the toilet paper taken from the toilet of the larger bathroom."

⁵ Prosecutors put forward an *implausible* motive of a sex-game 'gone wrong'.

4.3. Quantification and amplification of DNA

Before conducting the STR analysis, tests were carried out to quantify the amount of DNA (if any) in each of the seven samples. Sample A (taken from the knife handle) reported a concentration value of DNA of .08 nanograms per microliter; given the quantity of the sample, this amounted to a total of 4 nanograms of DNA, sufficient for analysis.

Samples D through G tested negative for DNA and samples B and C reported values too low to be quantified accurately. Samples A and B were subjected to capillary electrophoresis using the ABIPRISM 3130 Genetic Analyzer instrument and the analysis software “Gene Mapper.”

The quantity of DNA in sample A fell within the range suggested by the manufacturer of the kit used for the PCR reaction. With sample B, insufficient DNA was present to be quantified. This was therefore an undisputed low template (LT)-DNA sample, also verified by the borderline electropherogram. For purposes of interpretation, the alleles detected were extremely low level.

4.4. Sample A—the handle

The amplified DNA product in sample A was then subjected to capillary electrophoresis. The manual for the Applied Biosystems AB 3130 instrument used for the analysis recommends an RFU threshold of 50 and advises that one not go below this point (this guideline is in common use). The electropherogram showed peaks above the reporting threshold (50 RFU) and reasonable allelic balance. The DNA profile obtained from sample A matched that of Amanda Knox; to be specific, the likelihood ratio was calculated (my calculation using LRmix Studio)⁶ to be 700 million times more likely if the DNA was derived from Knox rather than an unknown, unrelated individual.

4.5. Sample B—the blade

The amplified DNA product in sample B was also subjected to capillary gel electrophoresis. The electrophoretic graph showed peaks that were below the reporting threshold and allele imbalance at most loci. I counted only 6 alleles that were above the reporting threshold. The electrophoretic graph showed a partial DNA profile that was claimed to match Meredith Kercher. Consequently, sample B was borderline for interpretation. For LT-DNA analysis, it is preferable to carry out duplicate testing [29,30] but the sample was not divided in order to carry out this procedure, hence the results of the analysis were not verified by re-amplification. Based on my own review of the electrophoretic graphs, the evidence only weakly supported the Prosecution's claim that the partial DNA profile belongs to Kercher.

The Marasca-Bruno Motivations Report, which quashed the convictions, was particularly critical about the failure to carry out replicate tests:

“...one must ask what the relative value can be to the proceedings if they do not permit repetition, regardless of the theoretical debate on the identification [of] more or less scientific of the findings of investigations carried out on samples so minuscule or complex.”

The police scientist stated that she ran a negative amplification control concurrently with sample “B” that had very low background noise⁷. This finding was interpreted as evidence that

the item was *not contaminated* in the Nencini sentencing report and this was a critical reason why the defendants were found guilty. The same error was also made in relation to the bra-clasp.

From the Nencini report

“Surely, because it was a low copy number, the sample taken from the knife's blade and identified by letter 'B' could not produce findings of certain attribution; nevertheless, this Court finds that the interpretation of the test is correct for the reasons highlighted above, because it is a trace that bears the presence of only one contributor, which make a test error less probable; also, the positive and negative checks established that there was no contamination of the item.”

“In conclusion, we must declare that with respect to Item No. 36 (the knife, the alleged murder weapon) and Item No. 165-B (the closure hook of the bra worn by Meredith KERCHER the night she was killed), no contamination or pollution has been proven or could be concretely possible. This assertion is also confirmed by the negative and positive controls (to be further discussed below) conducted by Dr. Patrizia Stefanoni and part of the trial record, which show that there was no contamination of said evidentiary items.”

However, this was also a serious error of interpretation. The negative control is simply a blank or empty tube run concurrently with the samples in the laboratory beginning at the extraction stage of the analytical process. Consequently, it can only be used as a control for potential reagent contamination. It cannot be used to discount possible contamination, either at the crime scene or in the examination room.

4.6. Subsequent analysis of sample 36(b)

Professors Carla Vecchiotti and Stefano Conti, who were the appointed independent experts by the Italian appeal court, also analyzed samples taken from the knife. The knife tested negative for blood. They also performed cyto centrifugation tests to detect cellular material, which revealed starch particles on the blade and handle of the knife, consistent with it being used to prepare food (starch was found on five samples, A, F (handle), E (blade), and H, I (point of contact between handle and knife)). If the knife had been used in the crime, the starch particles would have been expected to absorb blood. In addition, if the knife had been subsequently bleach cleaned, the starch particles would also have been removed in addition to any blood or DNA i.e. there was no evidence to suggest that the knife had been treated in this way. The DNA quantification did not reveal DNA suitable for further laboratory investigation; hence the independent experts did not perform an STR analysis of their own.

Even if one accepted that sample B contained Kercher's DNA, the presence of her DNA was more likely to be the result of a contamination event.

From the Marasca-Bruno Motivations Report:

“Also erroneous was the reading of the results of the genetic tests performed on Exhibit 36 and on the presumed compatibility of the seized weapon with the most serious injuries detected on the victim's neck. In this regard, it was obviously a distortion by the judge a quo [of the trial from which this appeal is being heard], given that no DNA mixture of Kercher and Sollecito was found on the handle of the knife. On the same utensil, traces of starch were found, evidence that it could not have been thoroughly washed to remove incriminating traces. In addition, starch, present in plants, is well known for its absorbent capacity, therefore it would have absorbed blood if used to commit the homicide.”

To address the question: “If the DNA on the knife blade was from Meredith Kercher, how did it get there?” Recall that the Massei

⁶ Available at: <http://lrmixstudio.org/>.

⁷ The court-appointed independent experts were not given the Italian laboratory's documents concerning control runs purportedly conducted on the machine used to test the knife.

judgement dismissed the premise of contamination based on the negative controls. However, it was common ground that Kercher had never visited Sollecito's apartment. The Marasca-Bruno motivation offered an alternative possibility of transfer method, namely, the utensil could have been used in the Perugia flat:

"taking into account the promiscuity and commonality of interpersonal relationships, typical of students living away from home, which make it plausible that a kitchen knife or other utensil could be moved from one home to another and that, therefore, the confiscated knife could have been moved by Knox to via della Pergola for domestic use, on the occasion of parties or other events, and thus also used by Kercher."

Of course this cannot be proven, but the purpose of the proposition was to counterbalance the prosecution speculation. The exercise is useful to demonstrate the imponderability of the various speculative causes of transfer.

In the final analysis, the collection of the item was not carried out in a formal way, thereby compromising the evidence. Indeed once evidence is compromised there is nothing that can be done to retrieve it.

From Marasca-Bruno:

"The big knife or kitchen knife, found in Sollecito's house and considered the murder weapon, was collected and then, preserved in a common cardboard box, of the sort used to package Christmas gadgets, namely agendas which credit institutions usually gift to local businesses."

4.7. The bleach cleaning hypothesis

The negative test results for blood on the knife were key pieces of evidence. Given the prosecution's theory that the knife was used to mortally wound Kercher, the primary question was whether there was blood on it. The answer to that question was undisputed at trial: *the knife tested negative for blood*. Of course, the absence of a positive test does not prove that blood is not present – but the alternative explanation is a *false negative* result, that cannot be proven. The presence of Kercher's DNA on the blade of the knife, if indeed it was there, was not relevant in light of the negative blood tests because the DNA could equally have been deposited via "accidental" transfer or some contamination event either before or after the crime had taken place.

Clearly, if the knife was the murder weapon then it must have been covered with copious amounts of blood. However, the only evidence put forward by the prosecution to suggest that the knife could have been the murder weapon was a rather weak DNA profile (much of it was below 50rfu) that matched Meredith Kercher on the blade of the knife, coupled with the DNA profile matching Amanda Knox on the handle of the knife, suggesting her to be the perpetrator.

In order to 'explain away' the lack of blood (and DNA) on the knife blade, the prosecution put forward the hypothesis that it had been cleaned, possibly with bleach. This was based solely on the premise that there was a 'strong smell of bleach' in the kitchen when Sollecito's apartment was investigated and the knife looked shiny, as if it had just been cleaned.

Even if we accepted that the DNA sample does in fact belong to Kercher, this does not tell us anything about whether the knife was used in her murder—whether the knife was the murder weapon was heavily disputed, and even the prosecution's expert

acknowledged the knife was not compatible with all of Kercher's wounds⁸. To reiterate, the DNA profile contained no inherent information about whether the DNA was associated with Kercher's blood or how or when the DNA fragments were transferred. This weak DNA profile was the type of profile that would be expected if the DNA fragments had originated from a contamination event. In addition, the knife tested negative for blood. The expectation is that any cleaning action powerful enough to remove the blood proteins would also have removed the DNA, leading to the logical conclusion that the DNA (if it belonged to Kercher) was more likely deposited as the result of a contamination event.

However this is another example of cognitive bias—working backwards from the assumption of guilt and literally pulling together an account of events that was based upon pure speculation that was completely devoid of scientific evidence.

4.8. Propositions relating to the use of the knife to stab the victim vs. using it to cut food

STR analysis does not offer any information about *when* or *how* the DNA was deposited on the knife. Knox had stated that she had used the knife to cook in Sollecito's apartment, and DNA would naturally be expected to have been deposited because of this activity. Surprisingly, the Massei report stated that the distribution of DNA on the knife handle supported the contention that it was used in an upward stabbing motion by Amanda Knox, rather than a cutting motion (e.g., to cut bread).

From the Massei motivation:

"It must be also emphasised that the presence of biological traces discovered on the handle of this knife, – and on which, regarding its attribution to Amanda, there was advanced no particular censure nor perplexity, – appears more likely to have been derived from her having held the knife to strike, rather than from having used it to cut some food."

And the justification for the conclusion follows:

"Remembering that this trace was found at the point in which the knife handle has a kind of upturn or rise, after which the blade begins, with the knife positioned thus in a horizontal position with respect to the plane on which one is cutting], it appears somewhat unlikely to hypothesise that such a biological trace would have come to rest at the point indicated. Conversely, should the cutting implement be used for striking, and therefore moving it not horizontally, but with a certain inclination, it is quite probable for the hand holding the knife to undergo a sliding motion due to the violence required for the blow and, finishing up with a certain violence against said upturn, thereby leaving behind the biological trace."

However, it is clear that this conclusion in the Massei motivation was pure speculation without any grounding in scientific analysis. There is not a single reported publication in the world that would support the notion that DNA analysis could reveal *how* a knife was used. DNA analysis, without additional supporting evidence, can only inform about the potential identity of the originator, i.e. *who*, but not *when, where, how, or why* transfer occurred [2].

4.9. Summary

To summarise, the assumption that the DNA had originated from blood was contrary to the scientific evidence. There was no

⁸ Professor Bacci testified for the prosecution that the knife was compatible with the largest neck wound, and that a smaller knife made the other wounds. The defense experts testified that the knife was not compatible with the neck wound or any other wound.

dispute that the tests on the samples were negative. There was also no scientific evidence that the blood-proteins could have been selectively removed with bleach while leaving the DNA on the blade. Bleach destroys DNA, and is used in laboratories for precisely that purpose. If bleach had been used to clean all of the blood from the knife, it is highly probable that it would have also destroyed any DNA on the knife. There is no accepted method that can be used to indicate whether the distribution of DNA on the knife indicated its use to stab the victim vs. to cut food.

5. The bra clasp

The identification of a DNA profile that matched Sollecito was a critical piece of evidence as it was the only DNA evidence found in the murder room that could be used by the prosecution to associate Sollecito with the crime.

5.1. Collection of the clasp

Police officers collected the clasp from Kercher's room on December 18, 2007—forty-six days after Kercher's body was discovered. During this period, the clasp was shifted to different locations around the room. Video evidence demonstrated that the officers did not follow proper procedures with respect to the handling of this item, e.g., they used non-sterile gloves, did not change gloves after touching a surface or item, passed the clasp around, and dropped it on the floor. The failure to adopt these measures was significant because Sollecito had frequented the apartment and had attempted to open the door to Kercher's bedroom prior to the discovery of her body on November 2nd, 2007. This could have been a source of contamination. There was no attempt made to take samples from the outer door handle. Gloves have been shown to be excellent intermediary substrates to transfer low levels of DNA from one object to another [31,32].

From the Marasca-Bruno motivation:

"Moreover, the clasp, although noted during the first site inspection by the Scientific Police, was left on the floor and remained there for quite some time. It is not true, moreover, that between the initial access and that during which the clasp was at last acquired, that there were only two site searches by the investigators, which were more numerous in reality and on those occasions everything was turned upside-down. In this regard, no account was taken of the defence's observations and of the conclusions to the contrary reached by the party's consultant, Professor Tagliabracci."

The method of collecting, handling, transporting, and analyzing the bra clasp did not conform with basic protocols to minimize risks of cross-contamination. There were numerous opportunities in this process for cross-transfer and contamination of the clasp.

From the Marasca-Bruno motivation:

"Regarding the possible contamination of the sample, the appellate judges ignored the photographic materials included in the court records, which clearly demonstrated possible contamination in the way the clasp was treated, being passed from hand to hand by persons wearing dirty latex gloves."

Comment: The examination of the bra-clasp at the crime scene was video recorded (this found its way onto social media).

5.2. Initial testing of the clasp

The clasp was not tested for the presence of blood, neither was any other laboratory test carried out to show the presence of any other biological material. However, it was subjected to DNA analysis. As with the knife, tests were carried out in order to quantify the amount of DNA. Quantification revealed an average

concentration of 0.115 nanograms per microliter, for a total quantity of extract of 5.775 nanograms, an amount permitting PCR amplification and STR analysis. Note that the majority of the DNA was from the victim.

The extracted DNA was amplified through the PCR process and then subjected to capillary electrophoresis. The electropherogram revealed a mixed sample—i.e., more than two alleles were visible at several loci. The results were interpreted and it was concluded that the sample was compatible with the hypothesis that the sample contained a mixture of Kercher's and Sollecito's DNA. Whereas it was possible to agree that the tests detected DNA matching the reference profile of Sollecito's on the bra clasp, it does not follow that this tells us anything about his presence at the crime scene. In light of the 46-day delay in collecting the clasp, the presence of profiles of other individuals in the sample (as discussed in the next section), and the failure to follow basic standard protocols for the collection and storage of the clasp, the evidence was irreversibly compromised. Consequently, the most likely explanation for the presence of Sollecito's DNA is that it resulted from a contamination event, although the specific route cannot be discovered.

Comment: The bra-clasp was crucial evidence for the prosecution case since it was the only DNA evidence to link Sollecito in the room of Kercher.

5.3. Subsequent testing of the clasp

Professors Vecchiotti and Conti also considered the clasp for further DNA testing. This was not possible to retest because it was rusted over. The electropherograms were re-interpreted.

The major profile was from the victim. Professors Vecchiotti and Conti pointed out the presence of one or more (unknown) minor contributors that were also present on the clasp, in addition to the component that matched Sollecito's reference DNA sample. There was a logical inconsistency in the prosecution case where it was assumed that the "known" individual is the culprit, whereas the "unknown" individual(s) were assumed to be irrelevant.

The Marasca-Bruno motivation was particularly scathing:

"[The appeal] particularly denounces the anomalies in the collection of the knife (Exhibit 36) and of the clasp of the victim's bra, anomalies of such relevance that the risk of contamination cannot be excluded, as correctly assessed by the Conti-Vecchiotti expert report, ordered by the Perugian Court of Assizes, that also considered the scientific result to be unreliable, precisely because it could not be tested again."

"The clasp was perhaps trodden on or, in any case, moved (such that it was found on the floor in a different position from where it had initially been noticed). Not only this, but the photographic documentation produced by Sollecito's defence demonstrates that, at the time of the collection, the clasp was passed from hand to hand by the agents, who in addition were wearing dirty latex gloves."

6. Other DNA evidence and the selective cleaning hypothesis

6.1. Kercher's Room

Numerous DNA samples were drawn from Kercher's room and her clothes, and Knox's DNA was not found on any of them. It was suggested that this absence may be explained by the fact that Knox selectively cleaned Kercher's room to remove her DNA while leaving behind the DNA of convicted-assailant Guede. Once again, this is evidence that the prosecutors 'fitted' an explanation to an inconvenient result.

There was no scientific justification for this selective-cleaning theory. DNA is invisible to the naked eye, and DNA can be

transferred to an object or surface simply by a brief touch. Once DNA is transferred to an object, it may transfer to other locations on that object or to an entirely different object. The only way to ensure that one has not left DNA behind in a room is to clean it with sterile implements while wearing protective gear. It is not possible to clean a room to selectively remove all traces of one individual's DNA whilst leaving behind another individual's DNA. Moreover, in a murder in which three people allegedly participated in killing a victim who was fighting back, each of the perpetrators' DNA could be anywhere in the room. Saliva, which is rich in DNA, for example, could be sprayed on different surfaces. It would not be possible for one of the perpetrators to even know where his DNA as opposed to the DNA of others was deposited. The perpetrators' DNA could also be mixed together and it would not be possible to somehow separate the DNA using household cleaning supplies.

The Marasca-Bruno motivation recognized the flawed argument:

"The hypothesis of an alleged selective cleaning of the crime scene by the defendant was completely illogical, with it being basically impossible to remove some genetic traces while leaving others untouched."

6.2. The shared bathroom

To reinforce the illogicality of the selective cleaning hypothesis, during the investigation, officers collected hundreds of DNA samples throughout the apartment and found Knox's and Kercher's DNA mixed in five of them. None of the samples were found in Kercher's room, and three were found in the bathroom that Knox and Kercher shared. These three samples were taken from areas of the bathroom with bloodstains.

This had been previously interpreted by the Massei motivation as follows:

"Amanda, soiled with Meredith's blood, entered the bathroom which was right next door to the room in which Meredith had been stabbed; putting her hand against the door she left a mark on it and the dribble of blood which remained is a sign [proof] of this, and left a mark also – still with Meredith's blood – on the light switch; she touched the cotton-bud box which was on the sink and left a mixed trace specimen of herself and of Meredith . . ."

Mixtures of Knox and Kercher were found in the washbasin and bidet and Massei inferred:

"an activity that, through the action of rubbing, involved the cleaning of the victim's blood, and could involve the loss of the cells through exfoliation of whoever was cleaning themselves: the two biological traces thus united together in that single trace."

These statements relate to the *activity* of transfer—not backed-up by any scientific evidence beyond the sub-source inference. There is an expectation that mixtures of DNA will be observed as natural background where people share premises. This expectation of mixtures also extends to visitors of premises. Therefore the limitations of interpretation of the DNA evidence are still firmly rooted at *sub-source* level.

As previously explained, there is a significant level of background DNA in any given environment. Premises will therefore contain considerable amounts of DNA from the individuals that inhabit them. DNA will be transmitted to surfaces and items by mechanisms such as touching, shedding skin cells, and saliva spray. Consequently, it is expected *a priori* that DNA of Knox and Kercher will be discovered in a shared bathroom. In addition it would be expected to find mixtures of their DNA – noting that DNA can be deposited at different times and by different body fluids, or by touch. There is nothing inherent in a

mixed DNA sample that indicates that the DNA fragments were deposited at the same time; the transfer of the DNA from the individual contributors can arise from independent events.

Massei went much further to infer a reason why Sollecito's DNA was not found in the bathroom, clearly starting from the premise of guilt, and working backwards:

"Raffaele Sollecito could have washed himself in the shower stall, in a different way and with an abundance of water, so that, either for one reason (no rubbing action, or not effected in the same way), or for another reason (use of water in large quantities), he did not leave his own biological traces while he was washing himself, or rather, he could have washed himself before Amanda, so that the water used by her immediately afterwards could have carried away the preceding possible traces."

This is another example of speculation leading to illogical deduction. Here we also see that hypotheses are continually put forward that cannot be tested scientifically.

The Marasca-Bruno motivation discredited the Massei motivation and postulated that the contact with the victim's blood was post-crime, again citing the lack of evidence in the murder room and elsewhere (although personally I think it more probable that Knox's DNA was present in the bathroom before the crime-event and the blood was transferred by Guede as he washed himself afterwards). Ultimately, this remains an example of speculative imponderability since there is no means to test the various explanations of the evidence (or lack of it).

From Marasca-Bruno:

"no trace leading to her was found at the scene of the crime or on the victim's body, so that – if all the above is accepted – her contact with the victim's blood would have occurred after the crime and in another part of the house."

The reasoning further cited the fatally flawed explanation of the selective cleaning hypothesis to remove the genetic evidence of Sollecito and Knox from the crime-scene room:

"After all, the assertion itself of a presumed carefulness in the cleaning is factually proven wrong, since in the "small bathroom" traces of blood have been found on the mat, on the bidet, on the tap, on a Q-tips box and on the light switch. And yet, had the defendants been guilty, they surely would not have lacked the time for an accurate cleaning, in the sense that there was no reason for the perpetrators to hurry up for fear of the possible arrival at home of other people. In fact, Knox was perfectly aware that Romanelli and Mezzetti were outside Perugia and would not have come back home that night, hence there would have been all the time necessary for a careful cleaning of the house."

7. Footprints in blood?

A number of footprints identified with luminol were discovered in the hallway, some of which (items 177 and 183) revealed a mixture of Knox and Kercher. Item 183 was reported as:

"compatible with the hypothesis of a mixture of biological substances, presumably containing hematic substances, belonging to Amanda Marie Knox and Meredith Susanna Cara Kercher."

Item 177 was similarly reported as:

"compatible with the hypothesis of an admixture of biological substances presumably containing hematic matter and belonging to Amanda Marie Knox and Meredith Susanna Cara Kercher."

However, the more specific TMB test was negative. The defence team argued that there was no proof that the footprints were blood as the tests were not confirmatory and there were known reagents that cause false positive results (like cleaning reagents). Therefore, it was not surprising that mixtures of Knox/Kercher were found in

the flat that they cohabited but this was interpreted by the Nencini judgement as proof that the origins of the footprints were directly related in a temporal sense to the crime event (the same error as described in the previous section in relation to the blood spots in the bathroom).

The Marasca-Bruno motivation dismissed this conclusion as “an obvious misrepresentation of the evidence”, citing the negative TMB test as a reason why the traces could not be definitively described as blood. In the Nencini report, the judges ‘overcame’ the difficulties of the non-specific luminol test by arguing (illogically) that its veracity had to be considered in context of the murder-scene, which made it *more likely* that the luminol test was associated with blood rather than being a false positive result. Furthermore they argued that the low levels of blood found were further evidence of the selective cleaning hypothesis.

Marasca-Bruno dismissed the argument: “*The weakness of the argument is such, already at first sight, that it does not require any confutation*”

Comment: To reiterate the point once again, if blood from Kercher was present in the area of the footprint, it does not mean that the DNA profile attributed to Knox was deposited at the same time. *A priori* we expect to find DNA mixtures of the inhabitants of a flat where the individuals live in close proximity. DNA mixtures may be found outside the area of the footprint. Distributions of DNA profiles will be present as part of the ‘natural background’ of the apartment.

8. DNA evidence relating to Rudy Guede compared to the absence of evidence from Sollecito and Knox

Rudy Guede was convicted of the offence of the murder of Meredith Kercher and this conviction has not been disputed. He had not previously visited Kercher’s apartment prior to the crime. Therefore the presence of his DNA was not explained by any legitimate reason for him to have been present at the crime scene. However, multiple DNA profiles attributed to Guede were in fact recovered, including: inside Ms. Kercher’s body, on her sweatshirt, on her bra, and on her purse, and in a toilet bowl in one of the bathrooms.

The numerous DNA samples taken from the crime scene attributed to Guede are consistent with the distribution of profiles expected from the perpetrator of a violent crime. In contrast, the DNA samples recovered from the knife blade and the bra clasp were the type of observations to be expected if the transfer had resulted from a contamination event. The strength of the evidence against Guede stood in stark contrast with the evidence against Knox and Sollecito.

To summarise the main points:

- Guede had no legitimate reason to be in the apartment.
- His DNA was found in multiple locations in the murder room and in the bathroom.
- Even though Knox lived in the apartment, her DNA was not found in the murder room.
- The only DNA attributed to Sollecito was a minor profile found on the bra-clasp.

The key consideration was the *distribution* of DNA profiles of Guede vs Knox and Sollecito. Multiple profiles from multiple evidential items are much less likely to all be contamination incidents, whereas weak (one-off) results are more likely to be contaminants—this was always a recognized difficulty for the prosecution who invented the selective cleaning hypothesis to explain away inconvenient results.

From the Marasca-Bruno motivation:

“It is indisputably impossible that traces attributable to the appellants would not have been found at the crime scene had they taken part in Kercher’s murder (the room was of small dimensions: 2.91 × 3.36 m, as shown in the plan reproduced in f. 76).

No trace belonging to them was found in particular on the sweater that the victim was wearing at the time she was attacked nor on her shirt underneath, which would have been the case if they had participated in the murder (instead, traces of Guede were found on a sleeve of the aforementioned sweater: ff. 179–180).

This aforementioned negative circumstance accords with the fact, already highlighted, of the absolute impracticability of the posthumous clean-up hypothesis, removing some biological traces while leaving others.”

9. The advice from the Marasca-Bruno motivation on the analysis of evidence

9.1. Objectivity vs. subjectivity

The advice from the Marasca-Bruno motivation follows:

“The rigorous respect of such methodical norms offers a conventional coefficient of acceptable credibility of such results, primarily linked to their reproducibility—namely the possibility of obtaining these results, and only these, reproduced with a constantly identical method and under identical conditions, according to fundamental empirical rules. On a more general level following the scientific method starting with Galileo Galilei on the application of the “scientific method”. This is typically leading to “objective” reality, reliable, verifiable and agreeable – well-known to be consistent, on one hand, in the collection of empirical data agreeable with the hypothesis and the theory to be validated; on the other hand in the mathematical and rigorous analysis, associating in this way – as first affirmed by the above-mentioned Galilei – “sensible experiences” to “necessary demonstrations”, that constitute experimental mathematics. As will be seen, all of this is essentially missing from the present trial.”

Here there is a plea for scientists to strictly follow the ‘scientific method’ that began with Galileo Galilei and formalised by Sir Isaac Newton. The standards of proof required in forensic science should be no different from any other science and practitioners must adhere to recognised scientific principles of objectivity where decisions are based upon a ‘collection of empirical data agreeable with the hypothesis to be validated’; ‘sensible experiences’ implies that an element of subjective opinion is acceptable to formulate plausible propositions, but must be tested by ‘necessary demonstrations’.

For a given set of data and case circumstances, the same conclusions are arrived at independently by different scientists using ‘objective inference’. Subjectivists emphasise ‘personal belief’ based on a knowledge base that may include vague notions such as ‘personal experience’. Whereas objectivism strives towards a commonality of approach so that different scientists reach broadly the same conclusions (a consensus).

There is little doubt that courts require an *objective* analysis and the role of the expert is therefore to reflect the consensus view of scientists, rather than to provide a purely personal viewpoint which is *subjective* so that a consensus viewpoint may be difficult to demonstrate.

Further discussion is needed within the forensic community. It is probably best to think of the terms *objective* vs *subjective* as representing two opposite extremes. It is unrealistic to suppose that a scientific rendition can be purely objective, as there is always an element of subjectivity. Deciding *plausible propositions* is often difficult—and perhaps this is where the main element of

subjectivity resides: 'Sensible experiences' requiring 'necessary demonstrations' implies that the onus is for scientists and investigators to think much more carefully about casework practices in order to provide empirical proof for any particular hypothesis that is put forward. The crime-scene has to be treated more as a 'research-project' with appropriate sampling, along with careful consideration about necessary controls in order to provide a sound basis for inferences to be put forward. The responsibility of the court is to provide a forum where critical peer review can take place, without bias.

9.2. The role of the judge and the burden of proof

The Marasca-Bruno motivation reminds us that judges typically have no scientific training and therefore cannot arbitrate as an 'expert of experts':

"[This idea] is in fact decidedly anachronistic, at least to the extent that it expects to assign to the judge a real ability to master the flow of scientific knowledge that the parties pour into the proceeding; a more realistic formulation, by contrast, sees the judge as wholly oblivious to those contributions, which are the fruit of a scientific training that he or she does not, need not, and cannot possess."

Within the constraints of the court-room, judges may themselves fall into the trap of *thinking* that they understand scientific arguments but this can itself lead to perverse judgments. For example, in relation to the question of whether contamination had/had not occurred, the judge in the Nencini motivation made the critical error of believing that the observation of clean negative controls was evidence that it *had not* occurred. This led to the 'reverse burden of proof' where the defence team had to prove that contamination *had* occurred, overturning the previous Helmann motivation who had correctly ruled the converse: responsibility rests with the prosecution to prove that contamination *had not* occurred. In practice, objective proof cannot be achieved either way, but this case was an example where sufficient doubt had been raised to elevate the possibility of contamination as a plausible explanation of the evidence. The Marasca-Bruno motivation provides the following guidance for judges, urging the adoption of an objective frame of reference that relies solely on evidence, putting aside personal 'feelings' about the guilt/innocence that inevitably invite cognitive errors found in the Nencini and Massei motivations. Above all, the judge must remain purely objective. If a hypothesis cannot be properly tested then he/she must acquit—perhaps the most important advice to be read from the Marasca-Bruno motivation is:

"In other words, the use of logic and intuition cannot, in any way, compensate for the lack of evidence or the inefficiency of the investigations. Faced with missing, insufficient or contradictory evidence, the judge should simply accept it and issue a verdict of acquittal, according to Article 530, section 2 of the Italian Code of Criminal Procedure, even if he is really convinced of the guilt of the defendant."

10. Summary of the critical errors that ultimately led to the wrongful convictions of Knox and Sollecito

- 1) Failure to utilize methods/procedures designed to minimise risks of contamination, thereby irreversibly compromising the probative value of the evidence.
- 2) Inferring 'activity' directly from DNA profiles found on the evidence (the CSI effect). For example the proposition that the DNA profile from Knox found on the handle of the knife confirmed the activity of stabbing rather than the activity of cutting food.

- 3) The assumption that DNA mixtures of Knox/Kercher identified as 'bloody footprints' using luminol was confirmatory evidence.
- 4) Applying illogical hypotheses in order to 'explain away' findings that were inconvenient to the prosecution including: a) the selective cleaning hypothesis b) the bleach cleaning hypothesis.
- 5) Lack of repeatability of the key DNA findings (the DNA attributed to bra-clasp and the DNA attributed to Kercher on the knife).
- 6) The mistaken belief by the trial judges that negative controls somehow provided a guarantee that contamination had *not* occurred and the application of the reverse burden of proof.
- 7) The assumption that the DNA mixtures of Knox/Kercher in the bathroom, was evidence that she had washed blood from her hands directly after the murder.
- 8) Finally, the distributions of DNA profiles were a critical feature. Contrast the widespread presence of Rudy Guede's DNA in the murder room, bearing in mind he had no legitimate access to the premises. In stark contrast, the DNA of both Knox and Sollecito was absent from the murder room (apart from the discredited bra-clasp DNA profile that matched Sollecito). This contrast is even more poignant given that Knox lived in the apartment with Kercher, and Sollecito had legitimate access. There is an *a priori* expectation that their DNA should be present at the crime scene.

11. Post-script: how many different 'miscarriages of justice' occurred in this case and how/why did they occur?

This question was motivated by an anonymous referee to this paper who asks "How many miscarriages of justice were there" and "could they have been averted?"

This case was unusual in that there was extraordinary worldwide publicity and scrutiny and it has been suggested that the prosecution machine was under pressure to produce results, and this in part led to the development of implausible propositions.

A miscarriage of justice relates solely to the event of the wrongful conviction an individual (there were two individuals hence the plural is used). However, the causes are typically propagated by multiple errors that are committed by all of the actors participating in the criminal justice system [2] —police, scientists, lawyers, judges. Examples of each are provided below:

- (1) The Bleach cleaning hypothesis was propagated by the police—see news report: <http://www.telegraph.co.uk/news/world-news/1569485/Meredith-suspects-DNA-found-on-knife.html>. Then the prosecution presented that theory at trial, eliciting testimony from one of the police officers that he sensed a strong smell of bleach while he was collecting evidence at Sollecito's apartment and that the knife looked very clean. As far as we can tell, there was no evidence presented from the scientific experts on this topic.
- (2) Testimony from scientific experts was misleading in at least one way. For example, the luminol evidence was reported as "presumably containing hematic substances," despite the fact that confirmatory tests for blood came back negative. It was also testified that there was no reason to think the bra clasp had been compromised when it was dropped to the floor during the police investigation. In addition, the Conti-Vecchiotti report described the lab report as lacking in important details and containing arbitrary theories that could not be scientifically determined.
- (3) It's hard to say how the judges on each panel dealt with and deliberated on the case—that sort of information has not been reported, as far as we know. However, it is safe to say that there is ample evidence that judges underappreciated the defense's

logical arguments. For example, Judge Massei accepted the prosecution's theory that Knox and Sollecito selectively cleaned the apartment of their DNA after Meredith was murdered.

- (4) Could this injustice have been averted? Bad practices in evidence collection and examination certainly played a major role. If the crime scene, or collected items are compromised, nothing can be done to retrieve the situation. There is only one chance to do things properly—we cannot go back in time. DNA evidence is given great weight at trial and the evidence can so easily be compromised.
- (5) However, the greatest responsibility to averting miscarriages of justice must reside with the judge, who is the 'gatekeeper', he must be completely impartial, and should at once recognize logical flaws in arguments, always erring on the side of caution. I therefore finish by repeating the poignant comment from the Marasca-Bruno motivation who issued the following guidance (section 9.2 above): *"Faced with missing, insufficient or contradictory evidence, the judge should simply accept it and issue a verdict of acquittal even if he is really convinced of the guilt of the defendant."*

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