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The Sydney declaration – Revisiting the essence of forensic science through its fundamental principles

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ABSTRACT

Unlike other more established disciplines, a shared understanding and broad acceptance of the essence of forensic science, its purpose, and fundamental principles are still missing or mis-represented. This foundation has been overlooked, although recognised by many forensic science forefathers and seen as critical to this discipline's advancement. The *Sydney Declaration* attempts to revisit the essence of forensic science through its foundational basis, beyond organisations, technicalities or protocols. It comprises a definition of forensic science and seven fundamental principles that emphasise the pivotal role of the trace as a vestige, or remnant, of an investigated activity. The *Sydney Declaration* also discusses critical features framing the forensic scientist's work, such as context, time asymmetry, the continuum of uncertainties, broad scientific knowledge, ethics, critical thinking, and logical reasoning. It is argued that the proposed principles should underpin the practice of forensic science and guide education and research directions. Ultimately, they will benefit forensic science as a whole to be more relevant, effective and reliable.

1. Introduction

Forensic science is seen as a mainstay of the criminal justice system. This view is contrasted by ongoing and sometimes significant debates about its effectiveness and reliability that have developed over the last decade [1-4]. Critical issues that have been identified and are most discussed include backlogs [5], quality management [6-9], bias mitigation [10,11], and evidence evaluation and communication [12-15]. Many partial solutions have been proposed over the years; however, forensic science remains in an intractable state of crisis [16-19]. This crisis could be explained, at least partly, by the fact that most issues have been presented through organisational lenses (legal or various scientific disciplines) rather than through the forensic science discipline lens. The assumption that organisational aspects are important is beyond debate. However, as explained by Roux et al. [20], 'means' and 'processes' "… are highly dependent on the local political and legal structures that essentially vary between countries, jurisdictions and organisations, it is difficult to identify and agree upon measures that are 'universal' and effective in the long term" (p. 678). In other words, the debate so far has primarily overlooked the overall purpose(s) of forensic science and its fundamental object of study in favour of organisational and more mechanical aspects of its use. It is time to overcome this stumbling block, one that had already been identified by Kirk [21] almost sixty years ago:

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"With all the progress that has been made in this field, and on a wide front, careful examination shows that for the most part, progress has been technical rather than fundamental, practical rather than theoretical, transient rather than permanent" (p. 235).

How forensic science is characterised or defined and whether there are sufficient common ground principles to develop it into a specific discipline are at the base of the current reflection. These principles may be critical to the advancement of the field, including in education, training, research and development, and operational practices [20]. Many authors have discussed these questions (e.g. [16,21-27]). However, unlike for more established disciplines, a shared understanding and broad acceptance of the essence of forensic science, and its objectives, purpose and fundamental principles are still missing. For these reasons, sixteen forensic scientists embarked on a reflection over a couple of years, aiming to define forensic science and its essence in the form of fundamental principles as concisely and comprehensively as possible. This paper presents the outcome of this work entitled the *Sydney Declaration*, inspired by the Ne'urim Declaration.[1]

The *Sydney Declaration* comprises a definition of forensic science and seven fundamental tenets in the form of principles to articulate the nature and the grounds of this discipline under a common framework, spanning the investigation of the crime (or an event of public interest) to the presentation of findings. The seven principles are:

1. Activity and presence produce traces that are fundamental vectors of information.
2. Scene investigation is a scientific and diagnostic endeavour requiring scientific expertise.
3. Forensic science is case-based and reliant on scientific knowledge, investigative methodology and logical reasoning.
4. Forensic science is an assessment of findings in context due to time asymmetry.
5. Forensic science deals with a continuum of uncertainties.
6. Forensic science has multi-dimensional purposes and contributions.
7. Forensic science findings acquire meaning in context.

At the outset, we recognise that some forensic practitioners may find it difficult to appreciate how these principles apply to their work. This may be especially the case for those practitioners in specialised sub-disciplines, often considered outside criminalistics,[2] whose everyday tasks could primarily define them as "analysts" or "technicians". For example, forensic drug chemists are often required to identify and determine the purity of drug samples submitted to them. Their function is essentially that of an analytical chemist. Through this perspective, it may be difficult for them to see the full value and impact of the *Sydney Declaration*. However, when adopting the perspective of illicit drugs as a holistic problem, the relevance of the concepts expressed in this paper becomes more apparent. In addition to answering to pure regulatory and investigatory functions, forensic drug analysis can (and should) also contribute to better understanding the broader drug problem. Examples include identifying and monitoring "hot spots" through rapid in-field testing, detecting and monitoring the emergence of new dangerous drug mixtures through street seizures and used paraphernalia analysis (e.g. discarded or exchanged syringes) or deciphering the illicit market or a criminal network through drug profiling and the analysis of the digital drug market place. Similar comments could be made for many other sub-disciplines, and it is beyond the scope of this paper to elaborate further.[3]

With this paper, we share our reflection for the international forensic science community to further its dissemination, acceptance and impact. One of our objectives is to help take a step back and integrate recent changes that are difficult to envision or operationalize within the "standard" laboratory framework. Examples include the decentralization of techniques, and more generally, many other digital transformations of forensic processes and crimes themselves. Forensic science laboratories will benefit from such a conceptual framework that will help them adapt to new realities. We welcome any thoughts or feedback from this community.

2. The Sydney declaration

The *Sydney Declaration* is presented in the boxes below,[4] along with annotated comments to assist the reader to appreciate the fundamental message conveyed by the declaration and its potential impact on forensic science practice and education.

Forensic Science Definition *Forensic science is a case-based (or multi case-based) research-oriented, science-based endeavour to study traces – the remnants of past activities (such as an individual's presence and actions) – through their detection, recognition, recovery, examination and interpretation to understand anomalous events of public interest (*e.g., *crimes, security incidents).*

This apparently simple definition underlies a very complex situation with many uncontrolled factors that necessarily impact the approach by forensic science. The first factor is the case, which may be legally defined as a specific crime or event by the first responder (or complainant/victim, etc.) either based on statements or by the initial impression given by a situation. The first corollary is that the case is not a reproducible experiment whose results can be repeated. Despite various recordings that may help provide a timeline and clarify aspects of the event or case, it is unlikely that an event can be reconstructed exactly as it occurred.

The second corollary is that the event occurred in the past, or is ongoing (*in flagrante delicto*). Therefore, the time between the event and its investigation is an important factor in the loss of information (whether physical, digital or memory-based).

Whatever happened, the forensic scientists start their investigation using circumstantial information (*Why was the event defined as it was? What are statements as to what happened? Is there factual information as to the position of objects, bodies, etc?*). All these elements will guide observations and searches for relevant traces that may contradict or modify the initial information under a different perspective, or to the contrary, help delineate and corroborate the understanding of the case. It must be emphasised that "*trace*" here is not defined "as something very small at the limit of sensitivity of analytical tools" as chemists would like us to believe. Still, a trace may be as large as a megalith or as small as a gunshot residue

[1] The concept of a declaration was inspired by the Ne'urim Declaration of 1995 that was instrumental to a significant scientifically-based and long-lasting change in the fingerprints area. A number of forensic scientists were meant to finalise and release the Sydney Declaration at the 2020 meeting of the International Association of Forensic Sciences (IAFS) in Sydney, hence the name. However, the meeting was cancelled due to the COVID-19 pandemic. The declaration was launched at a virtual global event entitled Forensic Science Principles – Paving the way for IAFS 2023, https://iafs2023.com.au/virtualevent/.

[2] While the term "criminalistics" is widely used in the USA, it is not common or is used inconsistently in other countries. Further, there is little consensus worldwide about how one field is positioned to the other [28]. In this paper we do not make any distinction and the *Sydney Declaration* applies across forensic science as a whole.

[3] While we have noted here that the correlation for other sub-disciplines is beyond the focus and purpose of this manuscript, we are hopeful that the *Sydney Declaration* and the corresponding IAFS 2023 agenda (see Appendix) will open inter- and intra-disciplinary conversation, debate and development utilising the declaration framework and its principles.

[4] In this paper, the *Sydney Declaration* is presented in a refined wording from the original launch https://iafs2023.com.au/virtualevent/. The authors hope that these small changes improve the accuracy and meaning of the message.

particle, or even an invisible signal that can only be detected through specialised physical or digital tools.

The 'research-oriented' aspect of the forensic science definition reflects the fact that the truth of the event is not known; it can be suggested, a victim can affirm it, but the reality is that only the actor (s), whose activities gave rise to the investigation, know(s) the true answer. In history, writing is often considered a piece of reliable information about events (but we all know that history may be re-written many times or that it may be distorted by the lens of the writer(s)), and factual elements may be reconstructed through historical remnants (stones, wood, pottery, skeletal remains, etc.) that may not fit historical writings. Forensic science is looking at such remnants, traces, that are allegedly contemporary to the event and, because they have a physical reality, they may be analysed, measured, and compared. All measurements, analyses and comparisons may not lead to a single and definitive description of the events and their protagonists, but by the fact that they have been found in certain positions, on particular objects, etc., they will limit the number of possible causes and one explanation may become apparent for the investigation. Forensic science uses observation, analyses and reasoning to interpret its findings in the face of various propositions regarding the case. It is knowledge by discovery and scientific assessment.

A final corollary to this definition is the necessary proximity of the forensic scientist to the scene of the event - whether physically distanced from the scene or not present in the initial stages of the investigation (in which the assessment and collection of traces is conducted by a third party with some degree of training) is introducing a further factor in the loss of primary information, i.e. time and distance combine to limit the potential offered by forensic science.

The definition highlights two essential results that forensic science can offer: identification and the description of activities that may link a given identified source to a given result whose causal relationship may be a convincing element for a decision-maker. The causal relationship is particularly useful in repetitive cases by serial or linked offenders (this is the reference to 'multi-case based' in the definition). Finally, this science is not predictive (as in physics, where a result can be predicted when setting up an experiment) but is retrodictive, providing potential explanations for the presence of relevant traces.

This definition and the very complex situation it underlies allow for the development of the following seven fundamental principles.

Principle 1. Activity and presence produce traces that are fundamental vectors of information.

*A precondition for a forensic science investigation is that activities cannot occur without leaving traces. Sometimes they are left at the scene; sometimes they are taken away (Locard's exchange maxim). The nature of the activity influences the types of items that are exchanged, and how and where they are dispersed in the environment. This item(s), a remnant of the investigated activity, is the trace. The trace is a vector of information that is capable of being detected, recovered, examined and interpreted. The traceability of human activities is rapidly changing in our digitalised (*i.e.*, combined physical and digital) environment. The place of forensic science is therefore increasingly central to studying events of public interest, which are themselves in transformation.*

The central tenet for defining forensic science is that traces are the fundamental components of the physical or digital record of an event or sequence of events. The trace is a vestige, or remnant, of an investigated activity [29]. As a vestige, the trace indicates a former presence or action, meaning that it provides a link to what it was once associated with (source) and the means by which it was left (activity). Prior to collection and laboratory analysis of the trace, its detection is a key component of any investigation. In order to effectively detect traces and assign them meaning, the forensic scientist must consider the creation of the trace. The creation of the trace has several important components for consideration by the forensic scientist at the scene. These include the nature of the source, the nature of the trace, the environment, exchange mechanism (transfer), persistence, and time (for a detailed description of trace creation, discovery and relevance, see Hazard & Margot [30]). Asking the right questions at the initial stages of an investigation, such as *What is the nature of the trace?*; *Where can these traces be found?*; *To what event(s) do these traces point?*; and *What is their value?* are critical to addressing larger questions of reconstruction: *Who? What? Where? When? Whom/What with*? and *How?* Moreover, the latter questions require contextual information and broader knowledge of crime and criminal behaviour.

Understanding the movements of the trace-generating entities (e.g. perpetrator, victim, object) within the scene can provide information about what types of traces may be deposited and their potential locations and characteristics. Reference to the exchange mechanism draws a connection to Locard's exchange maxim, which states:

"The truth is that no one can act with the intensity required for criminal activity without leaving multiple signs of his/her passage (...) The types of evidence I want to show here are of two kinds: sometimes the criminal has left signs of their presence at the scene, sometimes through inverse action he/she has taken with them on their body or their clothes signs of their presence or of their actions. Left or taken, these marks are of extremely different sorts" ([31], p. 139; translated by the authors).

Unfortunately, Locard's exchange maxim has lost much of its utility in modern forensic science by being reduced to 'every contact leaves a trace.' This is because the reduced statement does not account for the need to consider the nature and activity components of the traces (Locard's signs) left behind [32]. Further, the abbreviated formulation does not consider the correct inference rule ('abductive' process) that starts from the effects to the possible causes, essential for addressing the question, *what activities could have caused the trace?* [33].

Upon finding, detecting and recognising traces, they must be assigned meaning. The forensic scientist must have knowledge of the environment and its traces to effectively distinguish background traces inherent in the environment from those that were generated during the event(s) in question. Elements of trace creation, discovery, assignment of meaning, and analysis require the forensic scientist to reflect on Kirk's principle of individuality. When viewed as a fragmented specimen that has a shared uniqueness with its source, "a thing can be identical only with itself, never any other objects, since all objects in the universe are unique" ([21], p. 236). Considering Kirk's assertion, the forensic scientist attempts to move toward uniqueness through comparisons and exclusions. It is important to note that this is a process, not an end goal—the forensic scientist must be cautious not to declare 'matches' or unequivocal certainty where they cannot or do not exist. Since the forensic scientist utilises traces to gain knowledge about past events and works within a historical framework, the fragmented nature of both the traces and the associated historical record precludes the arrival at certainties in reconstructing past events (see Principle 4).

Finally, as described in Principle 6, traces feed investigative and intelligence efforts. Traces, both physical and digital, can and should play a principal role in the larger criminal justice system framework. Forensic science should not be solely justice or litigation driven, but be concerned with potential contributions to policing, security, and broader criminal justice matters, both practical (e.g., crime prevention) and theoretical (e.g., criminological).

Principle 2. Scene investigation is a scientific and diagnostic endeavour requiring scientific expertise.

*The goal of the scientific investigation at the scene is to infer (*i.e.*, reasoning under uncertainty) the reconstruction of an event through the study of the surviving traces. The site of an event is where relevant traces can be recognised and characterised with respect to their relative position that may be indicative of sequence, orientation and interaction. This information combines to help understand a limited number of potential explanations relative to the traces that need further examination and interpretation in the reconstruction and identification processes. This complexity requires a trained mind with broad science knowledge and with powerful and proficient observation and detection skills that may be extended by various scientific tools.*

Crime scene investigation and reconstruction are the most intellectually challenging and demanding activities within forensic science [34]. Unfortunately, scene "investigations" have been reduced to a technical exercise in recovering obvious traces (e.g. fingermarks, bloodstains), rather than an intellectual, analytical exercise requiring scientific interpretation through consideration of facets ranging from the event under investigation to the nature of traces. In the existing framework, most of what is actually done is crime scene processing—rote documentation, collection, and preservation of traces. It is not enough to collect objects from a scene blindly without considering matters such as their location and distribution (e.g. relative to other objects), their orientation, their production and mechanism for transfer and retention, and their significance and relation to the act itself.

Interpretation of traces to reconstruct events presupposes knowledge of understanding of semiotics (signs) (see Principle 3). Observing the trace alone is not sufficient for that trace to become relevant and a sign with all its potential meanings developed in semiotics [35]. The trace exists but it must be decoded, or interpreted by an interpreter. In other words, a generalist knowledge base is required to explicitly recognize and understand traces and use inferential reasoning to interpret and assign significance of the traces to the task at hand (the event, such as the crime).

Events, subject to forensic investigations, typically take place at a site or scene(s) and produce a natural record of activities, which is comprised of component traces. The resultant traces, when recognized, examined and interpreted, can provide profound scientific insights into the event which produced them to facilitate an understanding of it. Traces are produced according to natural laws. Thus, natural laws constrain and shape the production of the record. Scientific expertise is necessary for maximizing the extraction of information and for developing inferences from the traces. It is essential that the scene investigator is a scientist possessing an in-depth understanding of relevant natural laws. It is the fundamental scientific backbone of the forensic scientist that allows for the application of such natural laws to the investigation and recovery of meaningful traces.

The generalist forensic scientist is the lynchpin of scientific scene investigations—equipped with a broad scientific knowledge augmented with comprehensive knowledge of forensic science, traces, criminal investigations and criminal behaviour. Generalist forensic scientists should be present at the scene from its initial investigation. Despite technological advances that can be utilised on-site, the recognition, signification and interpretation of traces require human intervention based on scientific knowledge and reasoning. The investigation and reconstruction of a crime scene should be the undertaking of a generalist forensic scientist possessing the education, training and experience to conduct meaningful investigations in which the scientist can communicate effectively and clearly to stakeholders (e.g. law enforcement, jurists, laypersons) their analytical reasoning and methodology as applied to their examination and interpretation of traces and their role in the broader criminal investigation.

Principle 3. Forensic science is case-based and reliant on scientific knowledge, investigative methodology and logical reasoning.

Traces constitute signs and forensic science engages a scientific process to investigate and understand the meaning of these signs with their ambiguities, misperceptions and strengths. This engagement involves asking relevant questions (mostly context dependant), making observations, forming propositions and testing those propositions[1]*. This testing may include measurements facilitated by technology, but such tests are only an extension of the scientific process. The process is characterized by critical thinking, logical reasoning (deductive, inductive, abductive and analogical), problem solving and informed judgement. This approach is rendered ineffective – and perhaps even counterproductive – if it is not applied within a logical framework using a well-understood investigative methodology.*

[1]The original *Sydney Declaration*'s wording (available from https://iafs2023.com.au/virtualevent/) used the term "hypotheses" instead of "propositions". The former term is part of the philosophy of science discovery. However, as explained in the Definition, forensic science focuses on cases (case-based). These are defined as cases because they have a legal definition, or they are offered as a specific story line by victims, witnesses, first responders, persons of interest which are all propositions relating to the case. The term "propositions" is deemed more adequate in this situation.

Once the trace has been understood as the focus of our scientific interest, as described in the Definition and Principles 1 and 2, and recently emphasised by Ristenbatt et al. [28] and Jaquet-Chiffelle & Casey [36], it becomes necessary to address the forensic science method, i.e., how science participates in an investigation or a juridical decision. Expressing the forensic science method is the aim of Principle 3 that contains four main concepts about (1) the role and limitations of testing, (2) the requirement for a logical framework and an investigative methodology, (3) the decipherment of traces as signs and (4) the need for critical thinking, logical reasoning, problem solving and informed judgement. These concepts are discussed further below.

1. The testing may include measurements facilitated by technology, but such tests are only an extension of the scientific process.
   The need for a scientist to apply reliable analyses and measurements is beyond debate. However, such testing cannot be substituted for the scientific process itself. Tests are tools like the magnifying glass, the antibody test for COVID-19, the telescope for the astrophysicist, etc. They do not constitute the science or the knowledge base on which the test relies. They are an extension of the senses of scientists to uncover features, measurements or outcomes that they suspect will highlight relevant information. As quoted by Cleland [37], "A salient example is the use of radiometric dating methods, which are grounded in the highly stable, statistical laws of quantum theory. It is clear, however, that generalizations of this sort play a secondary role in historical research. They are not the targets of historical research but rather useful tools borrowed from other disciplines for special purposes" (p.565-566).
   Technology is now so refined that, most of the time, it offers reliable (accurate and precise) results. Most uncertainties usually come from the variable qualities of traces (inhomogeneity, the impossibility of statistical sampling, etc.). It is unfortunate that most efforts regarding quality focus on tools rather than on enhancing the process from the scene. Many laboratories use normalisation, accreditation and certification to cover their lack of control over detection, collection, and relevance. This costs a misguided fortune and is only a short-lived solution leading to less than satisfying results.
   At this stage, the critical question becomes: is this formalism sufficient to support investigations and adequately answer questions from triers of fact? Has forensic science become more

efficient (as opposed to reliable) since the efforts in normalisation, accreditation and certification have been introduced? Point 2 explains this challenge.

2. The forensic science approach is rendered ineffective – and perhaps even counterproductive – if it is not applied within a logical framework and using a well-understood investigative methodology.

Indeed, this appears to be a more general or meta-problem. In other words, can we improve the system by:

- focusing on methods and performance indicators such as the error rate, when the major uncertainties are specific to the investigated situation and the traces?
- increasing complexity through validated laboratory quality controls?

As expressed by Goldstein [38] in his discussion about means vs ends, "All bureaucracies are becoming so preoccupied with running their organizations and getting so involved in their methods of operating that they lose sight of their primary purposes for which they were created" (p. 242). Hence, did we lose sight of the forest because we are focusing too much on the trees?

3. Traces constitute signs and forensic science engages a scientific process to investigate and understand the meaning of these signs with their ambiguities, misperceptions, and strengths. This engagement involves asking relevant questions (mostly context-dependent), making observations, forming propositions and testing those propositions.
   The broad forensic scientist's purpose is to help a decision-maker (e.g. a judge, a jury, a chief of police, an investigator or a military commander) to make a risky decision. The decision-maker must acquire a sufficient belief (proof) about a reconstructed past (i.e. answering the circumstantial 5Ws and H, (*Who, What, Where, When, Whom/What with*, and *How*). In this case-based approach (*casuistic*) or singular task, the forensic scientist's job is to evaluate whether traces become proofs for the decision-maker. This approach is quite a blurred process exacerbated by the use of the pervasive term *evidence* in the English language. The path trace-sign-clue-proof may not always be straightforward, but instead moves through a complex transformation through reasoning (for further reading, see Crispino et al. [39], for example). However, this approach calls for an unavoidable acknowledgement of the investigative methodology, which is also relevant to the scientist, whose mission is hopefully based on robust, relevant scientific knowledge. Acknowledging this challenge invites us to understand the ontological uncertainty of traces and the limits of our inferences to be balanced in transparency with the forensic scientist's institutional position, habits, processes, and constraints (what Nobel Laureate Herbert Simon labelled administrative behaviour, or "getting things done").
4. The forensic science process is characterized by critical thinking and logical reasoning (deductive, inductive, abductive and analogical – see [33], for example). The latter leads to problem solving and informed judgement.

The initial phase is not univocal and may be seen as a constant flow between various logical processes. Given circumstantial elements and scientific laws, one may say, "if it happened like that, then I should find/observe this result (trace)", which would be deductive. But one may observe a trace/object that seems out of place, and given knowledge of scientific laws, one may decide that if this is observed, there may be an obvious cause or many potential causes (some more probable than others), giving rise to an abductive form of reasoning. This, in turn, may lead to a conclusion that "if the first obvious cause is right, are there other observations/traces that I should find (deductive) and if not, is there another trace that the second cause may lead to", etc. Kwan [40] concluded in his thesis that the main thought process of forensic science is hypothetic-deductive (abductive-deductive). However, in serial crime, finding comparable traces in two apparently unrelated cases (but similar modus operandi), the reasoning by analogy becomes apparent. Logical reasoning and inferential processes are part of human nature and constitute the backbone of scientific discoveries, but these processes should be well understood and categorised in forensic science. This is because forensic science always deals with uncertainties, as each case is a research problem that needs a multi-pronged approach underpinned by a strong abductive component which may be less present in other scientific endeavours.

In short, Principle 3 highlights that opinion and interpretation are first and foremost signification and meaning, and therefore acknowledges a semiotic dimension in the backbone of forensic science reasoning [39].

Principle 4. Forensic science is an assessment of findings in context due to time asymmetry.

In many instances, the quality of the trace resulting from an activity is such that it is incomplete, imperfect, and/or degraded by the passing of time, with such losses increasing uncertainty and often supporting only approximations concerning the past event under investigation. The ground truth remains in the past and is largely inaccessible. Forensic science can only be used to construct a model that is descriptive of a given scenario, explained by what is observed. The context is therefore essential. This is not a general model, but a specific retrodictive model that can only be inferential in nature. Forensic scientists cannot determine with certainty the definitive circumstances surrounding a trace, but only assess the relative value of associated findings under different plausible causes or scenarios. Such assessments should be unbiased and founded on scientific rigor and transparency.

One of the defining characteristics of forensic science is that it is concerned with reconstructing events or activities in the past. Since it is not possible to go back in time, this reconstruction has to be done based on traces that have been left behind as a result of that activity or event of interest. The ground truth remains in the past and cannot be revisited. Reasoning is applied to attempt to determine the causes (events or actions) based on the effects (traces). There will always be elements of uncertainty associated with the reconstruction inherent to the logical reasoning used in such a situation (see Principles 3 and 5).

The generation of traces is described in Principle 1. A single event or action results in a multitude of traces or effects. The asymmetry of time can be thought of as a cone, with the effects (or traces) following an event radiating out from the origin (event) with time. Before and after the event or action of interest, other irrelevant actions or events also occur and generate additional traces. One of the challenges is to distinguish between the relevant traces and those that are not relevant for a given context. Irrelevant actions or events that occur after the event of interest not only produce additional traces, they can also result in modifications of the traces of interest, which further complicates matters relating to reconstruction. In addition to this, time itself can also result in the degradation or alteration of the (relevant) traces of interest (this may lead to precise and accurate methodologies that determine that a trace can be excluded from originating from a specific source - outside the error rate of the method). Some of these irrelevant actions relate to the work undertaken by first responders and law enforcement. When this is the case, the forensic scientist should be given access to detailed descriptions of these actions to assist with the reconstruction.

Forensic scientists cannot determine with certainty the definitive circumstances surrounding the origin of a given trace. Events or actions often result in a multitude of traces or effects. As such, the reconstruction efforts must consider a variety of traces, the context in which they may have been generated, and how the passing of time may have altered and affected them. What forensic scientists can do is construct a retrodictive model to allow for the assessment of the relative value of associated findings under different plausible causes or scenarios. To arrive at a coherent narrative, the reasoning models used for this reconstruction and their challenges are described in some of the other principles. Forensic science is by no means the only scientific field that deals with this reconstruction of past events. These sciences are known as the historical sciences, examples of which include archaeology, palaeontology and astronomy. Interestingly, as explained by Cleland and Currie, the experimental and historical methodologies are different; however, none is superior to the other [37,41,42].

Principle 5. Forensic science deals with a continuum of uncertainties.

Forensic science deals with a continuum of uncertainties that are present at every step of the process that starts with the generation of traces and moves through all the steps up to the communication of the findings and value to the intended recipient (whether reported in written documents or in oral form such as their presentation in Court). Research is needed to identify and quantify these uncertainties with the knowledge that uncertainty will never be eliminated.

Uncertainties and their management are integral to the practice of forensic science. As explained in Principle 4, the ground truth about an event remains in the past (however it may be simulated through experimentation and reconstruction) and further, uncertainties are inherent to the logical reasoning used in forensic science (Principle 3). Uncertainties exist right from the outset. As described in Principle 1, trace generation forms the backbone for the reconstruction of past events. While following the laws of natural sciences for this generation, the trace is, however, “incomplete, imperfect and degraded by time passing, and these losses increase uncertainty or may support only approximations about the past event” ([26], p. 33).

The opportunity for:

- traces to be generated;
- traces to transfer between locations or spaces;
- traces to persist in a location or space;
- traces to be detected and recognised;
- traces to be recovered from their location or space;
- traces to be examined, analysed and compared; and
- the background abundance of traces to be known

are all critical in order to be able to reconstruct alleged activities. However, they are also highly variable, dependent on the case context and primarily uncontrolled.

Therefore, it is essential to acknowledge that uncertainties exist at every step of the process, and cannot be eliminated entirely. However, these uncertainties can be identified and quantified through research and eventually managed in practice. No matter how rigorous the validated method is, the interpretation and evaluation of the trace may need to be revised as new information or propositions become available within the framework of the case.

Research is essential to determine the boundaries of uncertainty encountered in forensic science so that traces can be exploited and their informative potential fully realised, including the effective interpretation and evaluation of their probative value within the framework of circumstances of an alleged event scenario. Moreover, research is critical to improve our understanding of trace generation, transfer, persistence, degradation, detection and recognition. While it is not possible to undertake a research project for each individual case, the body of knowledge developed through scenario re-enactment and modelling, when possible, constitutes a robust research-based foundation which can be used to assess many of the uncertainties. The creation of ground truth data sets, where samples of known provenance, age and or degradation status are characterised and monitored by analytical methodologies, can also assist in understanding the boundaries of detection and be used to assess some of the associated uncertainties.

The examination and comparison of specimens recovered from the crime scene, complainant/victim, suspect (or other relevant places and individuals) with reference samples relevant to the reconstruction of alleged event scenarios is a core part of the forensic science process. Such comparative analysis may involve well defined objective measurements where the uncertainties can be quantified and validated (for example, the analysis of a new psychoactive drug and its comparison with a known reference) or subjective measurements where the uncertainties may be less well defined and may depend more upon calibrated expert knowledge and experience (for example the comparison of tool marks, striations on projectiles, footwear marks or fingermarks).

Understanding the uncertainties associated with the interpretation, evaluation and the communication of analysis outcomes is also an essential component of the forensic science process. It requires research into transfer, persistence, bias, decision making and science communication. The ultimate outcome for forensic science is its communication within the Courts, which must occur so that the trier of fact can understand the value that the scientific findings contribute in their determinations. Beyond the Courts, challenges also exist when communicating with the variety of users and stakeholders of forensic science, for example, investigators, intelligence analysts, police administrators, military and other government officials. This public engagement of science requires research into forensic science ontologies as well as research into science communication, both written and oral, across the various relevant settings.

The introduction of virtual reality and augmented reality in documentation and training as well as artificial intelligence, machine learning and deep learning algorithms as tools in comparison, pattern recognition and decision-making processes is well developed in many disciplines outside of forensic science and is rapidly being adopted within some areas of forensic science (DNA and digital investigations). However, these advances must be introduced into forensic science in a manner that is fit for purpose and lawful (see Principle 6). As such, the uncertainties surrounding data generation, storage, curation, triaging, comparison, evaluation, disclosure, as well as ethical practices, biases and risk in decision making all require research to be undertaken to validate the approaches implemented and calibrate the associated uncertainties. In any case, such approaches do not intend to replace the scientist and human intervention remains necessary.

There is an opportunity to reshape the research culture within and across the forensic science landscape through interdisciplinary interactions between operational practice and academic researchers. Developing a better knowledge of deviant and criminal behaviour to understand traces, and vice-versa, is an obvious example (see Principle 6). The development of a culture of open science, unlocking the nascent data held within forensic science laboratories (for example from historical casework and within institutional databases and libraries) is technologically achievable. This generation of open data sets where researchers could then follow similar processes and methodology for foundational studies of, for example, transfer and persistence, enabling the aggregation of datasets to increase their power and usefulness is a meaningful endeavour [43]. Similarly, embracing citizen science approaches,[5] particularly background abundance studies, would vastly increase the understanding, interpretation, evaluation, and impact of traces enabling uncertainties to

[5] Approaches where public participation in scientific research enables advancements in scientific research through augmented capacity.

be defined and effective reconstructions to be undertaken. Such approaches have been enormously successful in public health and climate change studies, and as such proof of concept exists. Within forensic science, these approaches are within our grasp but need cohesion and leadership.

Principle 6. Forensic science has multi-dimensional purposes and contributions.

The purposes and contributions of forensic science are multi-dimensional. Through the systematic study of traces, forensic science (1) brings knowledge on crime, illicit markets and various mechanisms that cause harm or are of concern to society, (2) contributes to incident investigations, and (3) supports decision-making in legal proceedings. Forensic science provides the scientific basis for the practice of a variety of functions and professions related to crime, deviance and social response.

A growing volume and diversity of traces are produced as an effect of digitalisation [44]. Principle 6 emphasises forensic science's role in building approaches that allow for a sound, balanced, and proportionate "scientific" management of this new traceability of events of interest within broader security and criminal justice systems.

Principle 6 groups the multidimensionality of purposes and contributions into three subsets. They are distinguished by the global frameworks that guide interpretation, especially the nature of inferences and decisions in different processes with distinct objectives.

In the dominant expression of forensic science, traces are mainly exploited by supporting decision-making in legal proceedings (purpose 3 in the Principle) when well-formed propositions condition the evaluation of traces. This view expands to all types of regulation of human activities by law and rules (beyond criminal law enforcement).

However, as explained by Baechler et al. [45], the trial comes at the end of a multifaceted criminal investigative process that begins when signs are perceived that an event of interest has occurred. A close look at forensic practices (purpose 2) reveals that only a fraction of the traces collected at a crime scene ends up in a court of law [46]. Most of the information conveyed is used much earlier in the course of the investigation. They guide operations according to various objectives, such as establishing the reality of a crime, identifying, locating and arresting the presumed perpetrators, interviewing witnesses and suspects, and guiding multiple other searches. When an investigation begins, very little is known about the case. In the confusion (entropy) that characterises this situation, the processing of traces is first and foremost qualitative, a matter of imagination and associations of ideas. It aims to develop alternative explanations that will progressively constitute a framework for structuring the investigations. Beyond forensic scientists, many participants contribute through a collective commitment to integrating knowledge and data. They must comply with legal and procedural rules and pragmatic constraints such as timeliness and limited available resources.

Forensic investigation and evaluation (purposes 2 and 3, respectively) complement each other but must be combined with different paradigms and cultures (police investigation and justice). However, the best way to strengthen the evaluative part of interpretation is to capitalise on solid forensic investigations at their onset [47].

Forensic science can conjugate with many policing models beyond the traditional reactive law enforcement approach (purpose 1). Proactive policing styles (e.g. intelligence-led or problem-oriented) aim at crime prevention, harm reduction and crime disruption. These models take advantage of concentrations and repetitions of harmful events to ascertain crime patterns. The interpretation of traces can significantly support the detection and analysis of repetitive problems, thereby supporting crime prevention initiatives within the broader criminal justice system. This kind of integration is formalised and operationally implemented in a growing variety of trace-based crime analysis systems. Illustrations exist, for example, in areas such as high-volume crime, cybercrime, various illicit markets, the use of firearms, common causes and origin of fires, or identity document frauds [48,49].

More generally, trace interpretation helps decipher the mechanisms underlying many forms of crimes and harmful events taking place in both a physical environment and digital, computerised infrastructures. It is then evident that many criminological theories can be combined (e.g. environmental criminology) with a trace-based approach to produce new models and methods for studying crime and disorder, thereby establishing forensic science as a contributor to crime analysis and prevention (for a more detailed discussion about how forensic science can meet criminology through forensic intelligence, see [50]).

Principle 7. Forensic Science findings acquire meaning in context.

Forensic scientists need to act ethically and with impartiality, transparency and independence to ensure they remain true to science so that the information they provide for the potential resolution of the activity under investigation is useful and reliable regardless of who benefits from the information. Forensic scientists must defend their results and opinions as appropriate while acknowledging any plausible alternatives. When evaluating findings, at least two alternative propositions should be considered.

Forensic science findings acquire meaning in context rather than have an intrinsic value of themselves. This principle has profound implications and is not universally accepted by the broader scientific community and by stakeholders of the forensic science community, such as lawyers and law enforcement personnel.

It is useful to probe why this may be so. Forensic science findings play a critical part in judicial proceedings and are often mistakenly accepted as definite in their own right. This mistaken view misses the impact of context. The extreme view is that scientists who produce such findings should be isolated from all information to avoid bias. It would be foolish to ignore the existence of bias. Still, forensic scientists need to separate impacts of biasing information that can be avoided and contextual information that is vital to give meaning to the findings. The unwillingness to accept the impact of context might be confusing between irrelevant information, causing bias, and contextual information necessary to effect meaning.

The scientist needs strong ethics to distinguish between these two sources of information and, above all, needs to avoid interpreting their findings to suit the recipient of the information. The information, including the impact of context, needs to be the same regardless of who the recipient is. The scientist needs to defend their interpretations while being willing to accept reasonable alternatives. While easy to say, such an approach is much more difficult than repeating the findings in isolation.

The ethical onus on the scientist is to retain competence which includes keeping up to date with the impact context has on findings. Therefore transfer, persistence and background information are an essential part of the knowledge base of a forensic scientist when delivering results. The scientist needs to be transparent in their communication and capable of articulating the way in which they arrived at their conclusions, including the utilisation of contextual information to frame their interpretation. The forensic scientist rarely works alone. At the investigation phase, the forensic scientist delivers findings that may be even speculative in nature (within the confines allowed by nature's laws) and may work with the investigator to explore the effect of context. At the evaluation stage, when the scientist is advising the decision-maker, it is vital that the effect of context is clearly transmitted.

The ethical forensic scientist needs to be balanced and independent. This does not preclude working with others, but one's findings need to be based on scientific knowledge and data. While principles remain constant, knowledge and data will be continually updated. The contextual information from the investigation is also likely to change, which is a challenge to the forensic scientist both in maintaining independence and communicating findings. Considering probability of findings in at least two alternative scenarios is the framework to achieve this.

3. General discussion and concluding comments

As indicated in the introduction, the *Sydney Declaration* was meant to be a central piece of the 22nd Meeting of the International Association of Forensic Sciences in 2020 (IAFS 2020). When *'Where to from here?'* (WTFH) became the theme for IAFS 2020, thoughts turned to mini-summits for each sub-discipline such that each could set goals and priorities for the future. This was an important initiative. However, thinking more holistically about forensic science, the obvious question in addressing the theme WTFH was, do we have a solid understanding of 'here'?

For example, is the classic definition of forensic science as 'the application of scientific methods and techniques to matters under investigation by a court of law' still relevant when necessity and opportunity have significantly extended the scope of the discipline – from the courts to the policing and security space, and incorporating both investigation and intelligence; from crime resolution to crime disruption and crime prevention, and reduced public fear of crime? Is this where 'here' is?

There are 'principles' of science but are there equivalent and clearly articulated principles for forensic science? Is that where 'here' should be?

Is there a requirement for a paradigm shift? Roux et al. [51] suggested that, while there may be no need for a Kuhnian-type revolution at this time, "…a positive future definitely requires rethinking the forensics paradigm and revisiting fundamental forensic science principles" (p. 8). In further considering this thinking, what might 'here' look like?

The path forward should be aspirational and, unlike now, not focused on organisation, technicalities or protocols, and, crucially, there should be a globally shared understanding of forensic science and its principles. In turn, the principles should inform education, training, research and operational practices. They should also foster the development of a forensic science culture – instead of a primarily technological culture – unified by purpose and principles rather than means [20]. For example, one focus should be to educate forensic scientists first and foremost as *scientists* and not *technicians*, and ensuring that even specialist forensic scientists have a foundation in the generalist approach to forensic science.

It is now history that COVID-19 disrupted IAFS 2020, but it was agreed that the WTFH theme would carry over to IAFS 2023. It was decided that the *Sydney Declaration* would be launched prior to IAFS 2023 through an IAFS Virtual Event on Tuesday, 18 May 2021. The global response to this event was significant, with 1177 registrations from 91 countries. More than 550 delegates connected to the live event, and 133 questions were submitted. Eminent speakers from around the world presented and explained the proposed definition and the seven proposed principles.[6]

From the Virtual Event, it was clear that forensic science had to deal with uncertainty (Principle 5), and it would ever be with us. However, with the proposed definition and the seven principles, there is finally some direction to better handle uncertainties. The diverse nature of the foundation of forensic science, traces (Principle 1), and the investigation of them necessitates the application of science at the very beginning of each investigation – at the crime scene (Principle 2) – and throughout the forensic science continuum using appropriate logical reasoning (Principle 3). Context is all-important (Principles 4 and 7), as is the requirement to act ethically and with impartiality, transparency and independence. Alternatives must be acknowledged, but that which is scientifically defensible must be strongly defended. In Principle 6, there is an acknowledgement of the current and growing diversity of forensic science applications and their impact in addressing broader societal issues.

Who needs to know about this? It is forensic science managers, police, the legal profession, academics and students and, arguably and most importantly, forensic science practitioners – whether that be the crime scene investigator in Catherine, Northern Territory, Australia, the fingerprint examiner in Medicine Bow, Wyoming, USA, the drug analyst in Windhoek, Namibia, the DNA analyst in Quito, Ecuador, the trace evidence examiner in Tallinn, Estonia, or the forensic pathologist in Busan, Korea. There should be a clear understanding and a strong commitment from the international forensic science community and a drive to inform non-scientists (police, lawyers, jurists) of this fundamental foundation on which forensic science is built.

The definition and principles should underpin the practice of forensic science. The use of science and science-based methodologies must be acknowledged and advocated as the foundation of forensic science and agreement reached on the fundamentality of the 'trace'. The definition and principles should also be used to universally underpin and inform forensic science competencies. The competencies should, in turn, inform education and training and quality management programs. Agreed competencies should address both practical and cognitive aspects of forensic science and, along with education, training and quality management, address the totality of the forensic science end-to-end process. That is, include this thinking at the crime scene, during analysis and interpretation, and when formulating and communicating interpretations and opinions.

The *Sydney Declaration* provides the opportunity to clarify who we are and what we do as a professional community. It offers a positive perspective, focusing on forensic science rather than organisations and individualized, fluctuating approaches as to what forensic science should be based on the desired outcome or task-at-hand. A better understanding of the purpose and fundamental principles is an exciting path forward. It is hoped that more relevant education and research will also help shape the next generation of forensic practitioners, administrators and leaders. This is pivotal to the required cultural change.

The definition and forensic science principles that constitute the *Sydney Declaration* will be further debated and, where appropriate, modified as a part of IAFS 2023 (more information about the meeting itself is provided in Appendix). We see this as an ongoing discussion that will benefit forensic science as a whole so it can be more relevant, effective and reliable than ever.

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Claude Roux: Conceptualisation, Writing – review & editing. **Rebecca Bucht:** Conceptualisation, Writing – review & editing. **Frank Crispino:** Conceptualisation, Writing – review & editing. **Peter De Forest:** Conceptualisation, Writing – review & editing. **Chris Lennard:** Conceptualisation, Writing – review & editing.

[6] The full recording of the event is available at https://iafs2023.com.au/virtualevent/

Pierre Margot: Conceptualisation, Writing – review & editing. **Michelle D. Miranda:** Conceptualisation, Writing – review & editing. **Niamh NicDaeid:** Conceptualisation, Writing – review & editing. **Olivier Ribaux:** Conceptualisation, Writing – review & editing. **Alastair Ross:** Conceptualisation, Writing – review & editing. **Sheila Willis:** Conceptualisation, Writing – review & editing.

Declarations of interest

Claude Roux is President of the International Association of Forensic Sciences (IAFS). Chris Lennard, Alastair Ross and Claude Roux are members of the Scientific Committee for the 23rd Meeting of the International Association of Forensic Sciences to be held in conjunction with the 26th Symposium of the Australian and New Zealand Forensic Science Society, 20 – 24 November 2023, Sydney, Australia (IAFS 2023).

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Appendix

Where to from here for IAFS 2023.

So, where to from here in relation to the next IAFS meeting? It will be in Sydney in November 2023 and held in conjunction with the International Symposium of the Australian and New Zealand Forensic Science Society. For IAFS 2023, WTFH is retained as the conference theme as we believe that responses to this question will be more important than ever in a post-COVID world. Our planned in-person event in 2023 will cover 22 forensic disciplines – or, more correctly, sub-disciplines! – from Anthropology & Archaeology through to Wildlife Forensics & Environmental Crime, and including Forensic Medicine and Digital Forensic Science. With four nominated coordinators per discipline, this should ensure a memorable and thought-provoking scientific program. The complete list of disciplines can be found on the IAFS 2023 website (https://iafs2023.com.au/). We will be working closely with the discipline coordinators to choose noteworthy keynote speakers for each discipline to highlight current issues, ongoing research and future prospects.

The plenary component of the scientific program will include a session that will specifically address the WTFH question, with six diverse speakers providing their holistic views on the future of forensic science. In addition, individual WTFH panel sessions will be run within each discipline so that discipline-specific views can be captured. Delegates will be able to provide their own thoughts – over the full duration of the meeting – via a conference app.

After the meeting, all discipline responses will be collated to prepare a WTFH publication for one of the major forensic science journals. This process will capture and document the main points from these critical discussions. We see this WTFH publication as being one of the major outcomes from IAFS 2023 and an important snapshot in time for our discipline.

The WTFH theme and the WTFH components of the IAFS meeting were actually planned well in advance of COVID-19. As mass vaccination programs progress around the world, we are all hopeful of returning to some form of normal life sometime soon. However, it is clear that there will be a "new normal", and answering the question WTFH for forensic science is arguably even more relevant than initially envisaged. We hope you can join us in Sydney in November 2023 for what should be a memorable gathering of forensic science practitioners from around the world.

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