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Review article

Forensic science: Where to from Here?

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ABSTRACT

'Where to from Here' (WTFH) was the theme chosen for the 2023 meeting of the International Association of Forensic Sciences (IAFS). This theme reflects the fact that forensic science is evolving rapidly, not only within individual sub-disciplines but, critically, across the whole forensic science landscape. Identifying and predicting evolutionary change will enable a more focused and constructive future for forensic science. The IAFS meeting originally scheduled for 2020 was cancelled due to the global impact of the COVID-19 pandemic. However, on 18 May 2021, an IAFS Virtual Event launched the Sydney Declaration as an integral part of the WTFH initiative. The Sydney Declaration articulates a definition and seven principles for forensic science and provides a much-needed platform for forensic science into the future. It is aspirational, not focused on organisations, techniques or protocols, and provides a shared understanding of forensic science and its principles. The 2023 IAFS meeting built on the Sydney Declaration, with five themes developed as the basis for eliciting information from delegates related to the WTFH concept. The themes were: (i) integration and harmonisation; (ii) digital transformation; (iii) research; (iv) education and training; and (v) technology. Information across these themes was gathered via short, sharply focused panel discussions in the final session of each of the 22 disciplines represented at the meeting. In addition, there was a panel-based seminar on the Sydney Declaration and a panel-based plenary session on the conference theme. Meeting delegates were also able to provide their thoughts during the meeting, and for a two-week post-conference window, via a dedicated meeting app. Information from all of these sources has been collated to provide a consolidated WTFH landscape for forensic science.

1. Introduction

It is fair to say that the provision of forensic science has been challenged for quite some time. A Royal Commission on Criminal Justice in England and Wales was established in 1993 following several landmark and high-profile cases of wrongful conviction [1]. The Commissioner's report made direct reference to past failures of forensic science [2]. The National Academies of Science (NAS) report [3] and the subsequent President's Council of Advisors on Science and Technology (PCAST) report [4] are arguably still the most referred to of the external reviews. From an internal perspective, the literature is peppered with articles from the forensic science community challenging the status quo, and the effectiveness of forensic science.

Some relevant examples that have appeared over time include:

- Forensic Science Under Siege: The challenge of Forensic Laboratories and the Medico-Legal Death Investigation System [5]
- The end of the (forensic science) world as we know it? The example of trace evidence [6]
- Practical Solutions to Cognitive and Human Factor Challenges in Forensic Science [7]
- Challenges to reasoning in forensic science decisions [8]
- ISO-accreditation - is that all there is for forensic science? [9]
- Mind the gap: The challenges of sustainable forensic science service provision [10]
- The Sydney declaration – Revisiting the essence of forensic science through its fundamental principles [11]
- The influence of forensic evidence on the case outcomes of homicide incidents [12]
- What is the value of forensic science? An overview of the effectiveness of forensic science in the Australian criminal justice system [13]
- A different perspective on the forensic science crisis [14]

Forensic science is constantly being challenged, and that is not

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necessarily a bad thing. The challenges emanate both from within and outside of the broader forensic science community and demonstrate what is essentially healthy and ongoing internal and external scrutiny. However, it is also recognised that there is some risk associated with too much or unreasonable negativity in forensic science including a lack of confidence in our institutions and overlooking what often remains the most transparent avenue to address crime or security problems. It was this situation of constant challenge and questioning that prompted the choice of the theme 'Where to from here' (WTFH) for the 2023 meeting of the International Association of Forensic Sciences (IAFS) held in Sydney from 20 to 24 November 2023. The meeting was held in conjunction with the 26th International Symposium of the Australian and New Zealand Forensic Science Society (ANZFSS). The conference was, in part, designed to elicit information related to five themes relevant to the foundation and delivery of contemporary forensic science. These themes were: (i) integration and harmonisation; (ii) digital transformation; (iii) research; (iv) education and training; and (v) technology.

This paper reports how the information was gathered and collated and subsequently analysed and discussed to provide key findings and guidance for the future.

2. Materials and methods

2.1. Key information sources

The primary sources of information included discipline panels, conference app questions and feedback, plenary sessions, a seminar specifically focused on the Sydney Declaration, and previously published material. More details about these sources are provided in the following paragraphs.

2.1.1. Discipline panels

There were short, sharply focused panel discussions in the final session of each of the 22 disciplines represented at the conference. The panel discussions were based on specific questions related to the five themes (see Appendix 1).

2.1.2. Conference app

Information was collected through a Google form accessed through the conference app that led individual practitioners through the same set of questions. The app was accessible at the conference and for two weeks post conference.

2.1.3. Plenary sessions

The WTFH conference theme was reflected across four plenary sessions:

- Forensic Science in a Post-Pandemic World
- Forensic Intelligence
- Global Strategies on Gender-Based Violence & Missing Persons
- Where to from here?

The first three sessions represented challenges and opportunities for contemporary forensic science and the fourth was a panel discussion directly addressing the conference theme.

2.1.4. Sydney Declaration seminar

The Sydney Declaration (SD) heralded a fundamental and much needed rethink of what forensic science is through a definition and fundamental principles. It was the focus for an evening seminar held during the IAFS 2023 meeting and jointly hosted by the University of Technology Sydney (UTS) and the Australian Academy of Forensic Sciences (AAFS). The seminar took the form of a panel discussion, with the panel members representing forensic science in its broadest sense.

2.1.5. Previously published material

Throughout the document, we have referenced previously published material that introduces a theme/topic or reinforces and adds context to the information collected via the IAFS 2023 meeting.

2.2. Submissions

Submissions from each of the discipline panels and from the conference app, plus the individual presentations given at the WTFH Plenary and the SD seminar, were summarised. The summaries were then returned to the submitting author(s) for sense checking and editing, and any suggested changes incorporated into the individual summaries. There were 31 summaries in all that were separately circulated to and approved by the submitting author(s).

Even in summary form, there was too much information to include in a single publication. Therefore, the summaries were collated and key points, trends and common threads highlighted. These then became the primary content for this article.

3. Results against major themes

For this article, the original themes of Digital Transformation and Technology have been combined. Further, in collating the information submitted from the various sources two additional themes emerged from the five originally proposed: Culture and Professionalisation; and Practice, Skills and Competencies. Narratives have been provided for each theme.

3.1. Integration and harmonisation

Integration was one of the five themes for the WTFH discussions and it has been the subject of discussion within forensic science for many years [15–17]. It is crucial for intelligence purposes and, as advocated by Pierre Margot in his plenary presentation, it is essential for a holistic forensic science investigative perspective.

Despite common misunderstandings, the crime scene has been recognised for some time as a scientific problem requiring scientific expertise and scientific methodology [18] and this has been reinforced by the Sydney Declaration [11]. In accordance with this view, the practice of triage or whole of case coordination beginning at the crime scene is becoming more widespread in forensic investigation [19–23]. From holistic forensic science, investigative and resource perspectives, this just makes sense especially in an era of ultra specialization.

The current geopolitical environment and increasing incidents of natural disasters dictates an international effort from forensic science. For this to be most effective, there is a need for a common/shared forensic science culture – both inter-disciplinary and intra-disciplinary – leading to consistency in competencies, thought and approach. Globally and at the very least, forensic science response teams should have the same knowledge and operational skills without the need for additional onsite training. This is colloquially known as the 'plug and play' approach. Practical examples of these types of protocols are the Interpol Disaster Victim Identification (DVI) guidelines [24] and the Berkeley Protocol on Digital Open-Source Investigations for investigating violations of international criminal, human rights and humanitarian law [25]. However, this is not sufficient. Facilitated through education, all forensic science 'actors' also need to share a common culture and set of values.

The Sydney Declaration with its definition and seven principles of forensic science [11] provides an excellent vehicle for global integration and a renewed structural basis. It should be recognised as a crucial piece in the development of the common/shared forensic science culture mentioned above. With its pivotal focus on the trace, it provides the ideal basis for multi-disciplinary investigations, as illustrated by many comments made during the conference. For example, in her presentation for the WTFH plenary Rebecca Bucht, one of the authors of the Sydney

Declaration, acknowledged that:

> 'The reception of the Sydney Declaration has been more positive than I had dared to hope for.'

During the Sydney Declaration seminar, Sheila Willis, also an author of the declaration, stated:

> 'My hope is that this combination (definition and principles) can act as a unifying framework to deliver a shared understanding to stakeholders across the crime scene to court process. It can also provide a basis for forensic science courses so that graduates in future will have a common platform from which to branch out into their chosen sub discipline.'

Furthermore, Noel Woodford stated that, in relation to the principles of the SD, forensic medicine is certainly case based, its opinions reliant on reasoning, it is reconstructive (the 'what happened' specialism, where ground truth is most often not known or knowable), operates in areas of uncertainty, and is very context dependent.

On the Integration and Harmonisation theme, examples of discipline panel submissions were as follows:

- A more holistic approach to casework is required through greater engagement with DNA scientists and reconsideration of the value of nonmetric traits to augment the identification process [Anthropology & Archaeology].
- Integration is most definitely a key focus for the future. The days of traditional silos for operational activity are ending. An example is activity level reporting, incorporating multiple traces such as DNA and glass that could be recovered from a single criminal event [Biological Criminalistics].
- Existing silos means isolation of scientists from an integrated triage process [Chemical Criminalistics].
- Integration of digital and natural (physical) forensic sciences at triage is required to ensure a holistic answer to customer questions and best value for end users [Digital Forensic Science & Electronic Evidence].
- There needs to be closer cooperation with investigators and integration with other disciplines to better address investigative questions/capabilities, engage in data sharing and provide intelligence [Document Examination].
- Wildlife and environmental crimes can and do impact the environmental, social, health and economic security of nations and there are many occasions where traditional law enforcement would benefit from the expertise of wildlife and environmental forensic scientists and vice versa. Both Wildlife and Environmental Forensics often sit at the intersection of environmental biology/chemistry and forensic science. Better integration into both disciplines will further enhance forensic outcomes [Wildlife Forensics & Environmental Crime].
- Consideration must be given to greater collaboration between or a combination of forensic pathology and forensic medicine; this particularly relates to research [Forensic Pathology].
- There is a requirement for access to contemporary forensic technologies for the search, recovery and management functions related to unknown deceased persons investigations, including both genetic (e.g., STR and SNP testing) and non-genetic (e.g., anthropology, radiology, geochemistry, digital) capabilities [Humanitarian Forensic Science].
- With respect to quality integration and harmonisation, silos exist between disciplines and also between the different phases of an investigation. With respect to crime scene and laboratory silos, for example, feedback loops are essential for each phase of an investigation [Management & Quality Assurance].

Examples of the conference app submissions were as follows:

- While there are many locally based initiatives around integration and harmonisation, none of them have a global focus.
- While there is integration and harmonisation within Forensic Pathology, more is required in terms of policy, regulations and medico-legal procedures and engagement with the judiciary and law enforcement.
- There is a need to do more to strengthen the interface between forensic science and the legal profession.

3.2. *Digital transformation and technology*

3.2.1. *Digital transformation*

Digital transformation is having and will continue to have a huge impact on forensic science. According to Ribaux et al. [26], new, more easily transportable technologies are assisting the detection, collection and analysis of a large volume of new and more diverse traces generated by criminal activities. This is leading to a radical shift in roles and tasks within traditional forensic science and police structures, as well as in the criminal justice system.

Similarly, Casey and Souvignet [27] report that:

> "Technological advances are changing how forensic laboratories operate in all forensic disciplines, not only digital. Computers support workflow management, enable evidence analysis (physical and digital), and new technology enables previously unavailable forensic capabilities."

However, Casey and Souvignet offer a timely warning in that, without the necessary preparations, these digital transformations can undermine the core principles and processes of forensic laboratories.

Digital transformation has catalysed a rupture within the 'business as usual' approach to forensic science through the creation of a new class of traces (i.e., 'digital traces'). The challenges in this area are often referred to as the five Vs [28] – velocity, volume, value, variety and veracity – that underpin the dynamic nature of data use and management. The order of magnitude and variety with each of these dimensions are manyfold compared to conventional forensic science traces. Obviously, then, digital transformation requires new thinking, strategies and management practices.

To emphasise this, Wilson-Kovacs et al. [29] reported that 90 % of cases in England and Wales now contain a digital element and risks of ineffective practice are not confined to the digital forensic laboratory but are present throughout the journey of digital evidence within the criminal justice system. In his presentation for the WTFH plenary, Dean Catoggio highlighted society's increasing dependency on technology. The digital future is underpinned by 3.5 billion new internet users between 2020 and 2030 [30] and an extrapolated world data volume of 800 zettabytes produced in 2030 [31]. He questions how this will impact cyber security and supercharge crime, including domestic crimes such as family and sexual violence. Similarly, the WTFH panel discussion for Digital Forensic Science & Electronic Evidence reported that increased societal digital connectivity and dependence are exploited by criminals with access to cheap, high-powered devices. The panel advocated the development of a broad ethical and privacy framework to handle and manage big data sets (public, government and industry), informing forensic investigations, and a robust framework to triage massive amounts of data through new artificial intelligence (AI) tools that can efficiently search and classify relevant evidence from vast data repositories.

Indeed, within the various discipline WTFH panel discussions, databases were a common point of discussion. For example:

- Importance of comprehensive datasets for maximum use of AI/machine learning (e.g., ante-mortem data sets for odontology) [Odontology].

- Need for comprehensive databases (e.g., hair and fibre) to maximise benefits of AI and machine learning and for evaluative reporting and interpretation [Chemical Criminalistics].
- Discussion and questions around the public acceptance of private DNA databases and the implications of that [Biological Criminalistics].
- Database design and structure needs to provide actionable information from the data record for intelligence purposes, and/or to proactively inform operations [Crime Scene Investigation].
- Integration of technology into the discipline, with a comprehensive data management system that is broadly accessible [Clinical Forensic Medicine & Forensic Nursing].
- Access to both national and public DNA databases while ensuring proper privacy and security and databases able to effectively search ante-mortem and post-mortem data, including case and biometric data [Humanitarian Forensic Science].
- Commonality in laboratory information management systems (LIMS), additional data analysts and consistency and harmonisation of terminologies and descriptors are required to support data mining and this will be invaluable in directing improvements from crime scene collection to reporting [Biological Criminalistics].
- It is critical that, once a record is created, it is carried through the entire forensic science spectrum. Uniform technology can improve systematic record keeping and consistency throughout the laboratory. Furthermore, a contemporary information management system will provide data for modelling, analytics and quicker decision making [Management & Quality Assurance].

From a practical perspective, Caroline Gibb in her WTFH plenary presentation stressed the need to retain existing operational knowledge and skills in the light of digital transformation and AI ('don't throw the baby out with the bath water') and the importance of finding the balance and synergy between practitioner and machine. This requires a clear understanding of the limitations of both humans and systems, and knowing when it's best to rely on one, the other, or a combination of both, and **c**ombining human-based judgments with computer-assisted approaches. In his award presentation, John Buckleton emphasized the fact that standardization and quality assurance are not substitutes for expertise in forensic science and a sound understanding of the principles behind the tools and standards in use is required, particularly as such tools become more advanced.

Examples of the conference app submissions were as follows:

- The production of large amounts of data is not supported by global standards for storage and usage.
- Ongoing privacy concerns with data repositories.

3.2.2. Technology

From a technology perspective there has been a focus on miniaturisation and mobility. Kloosterman et al. [32] reported that:

"…technological developments are creating new possibilities to perform robust scientific measurements and studies outside the controlled laboratory environment. The benefits of real-time, on-site forensic investigations are manifold and such technology has the potential to strongly increase the speed and efficacy of the criminal justice system."

Along the same lines, the Australia New Zealand Policing Advisory Agency (ANZPAA) [33] noted that recent technological innovation has led to the development of portable, compact, robust, low cost, smart and network ready devices ideal for use in the field. The potential benefits of using this technology in the field include:

- Provision of rapid analytical results to expedite decision making by forensic examiners and law enforcement personnel at the point of response.
- Evidence can be analysed in situ in its most original state, reducing the risk that evidence is analysed following damage, deterioration or contamination possibly due to handling, transportation and storage.
- Automated analysis and machine learning embedded devices enable operation by non-scientific personnel.

There is some debate as to whether expectations in relation to this have been met and as a word of caution, where implemented, this approach has led to a shift in the dynamics of the exploitation of traces from the forensic laboratory to first responders. It has implications for the scientific necessity of scene processing and the interpretation and contextualisation of results. It requires a re-evaluation of the veracity of the forensic science continuum. It also prompts laboratories to better express their value proposition in the whole process as, otherwise, they may rapidly lose their relevance [34].

The WTFH discussion panels highlighted the following:

- New technologies and research related to machine learning/artificial intelligence must be targeted, operationally relevant, and readily accessible to laboratories and practitioners [Document Examination].
- Increased investigation and exploitation of technology is required to assist forensic document examiners in various aspects of their work including recording exhibits, optical character recognition to extract handwritten text, and compiling characters for comparison. Machine learning should be used for recognising patterns in various data for intelligence purposes or to provide an evaluation of evidence [Document Examination].
- Technologies such as CCTV and bodycam footage are useful for scene reconstruction and gunshot residue (GSR) interpretation, for example, but the time for viewing these in the sequence of an examination must be carefully considered due to bias concerns [Firearms & Toolmarks].
- Wearable devices such as smart watches can provide clues on location and time of death [Digital Forensic Science & Electronic Evidence].
- Remote drone/robot examination of scenes will play an increasing role in human–machine interactions [Crime Scene Investigation].
- At-scene digitisation of notes needs to be exploited [Fires & Explosions].

- Big data, machine learning, artificial intelligence and technologically advanced methodologies are valuable tools but do not replace the need for rigorous statistics, data analysis, probabilistic reasoning and skilled practitioners [Science, Justice & Legal Issues].
- Increased development of methods and workflows that allow a high degree of automation, such as lights-out workflows for fingerprints and for biology in no-suspect crimes. The future here lies in implementing many of the current proof-of-concept automated workflows to remove repetitive, administrative or pattern recognition tasks [Biology Criminalistics].

3.3. Research

Research is defined as the creation of new knowledge and/or the use of existing knowledge in a new and creative way so as to generate new concepts, methodologies, inventions and understandings [35]. In the ever-evolving world of forensic science, research is crucial.

However, in most forensic science facilities without a dedicated research capability, relevant foundational research is limited mainly due to critical funding restrictions, limited research skills, lack of a research culture, casework demands and time constraints. These same barriers can also make uptake of research outcomes difficult [36]. The research that is carried out by operational facilities is largely case based. In a recent article by Neuteboom et al. [37], it was the authors' perception based on observation and the number and source of forensic science

articles being published and their specific content, that present laboratory systems did not facilitate research. The WTFH discussion panel for Biological Criminalistics expressed a similar view, reporting that few operational laboratories have funding allocated to research and development to the scale needed to employ postdoctoral fellows. Therefore, much in-house research is performed on shoestring budgets. Small-scale case-based research projects, while beneficial, are limited in scope and unlikely to create a step-change in the overall forensic process. However, such step-changes are needed for the advancement of forensic science into the future.

In 2011, there was a government-led review of research and development in the UK [38]. In the same year, Mnookin et al. [39] published a paper titled 'The Need for a Research Culture in the Forensic Sciences'. Margot subsequently emphasised [40] the additional need for this research to consider a forensic science culture to address relevant forensic science questions.

Little has changed since the abovementioned publications as, in 2023, Weyermann et al. [41] stated:

> 'Over the years, forensic science research has remained largely oriented towards methodological and technological development rather than relevance to the forensic science discipline and practice.'

In the conclusion to their paper, these authors call for:

> '…well established researchers and managers in universities, funding agencies, publishing houses and forensic laboratories, to slow the frantic chase towards metrics (i.e., quantity and apparent novelty) and start *increasing critical forensic thinking to address longer-term real life, as well as fundamental, challenges in collaborative enterprises.'*

There has been a focus on research aimed at providing technological solutions or improving methods (often from other disciplines), but with little attention to how these outcomes impact forensic science practice. As a result, more pressing and relevant issues in forensic science, such as trace ontology and its significance, are often overlooked.

As with education and training, it is essential for there to be strong partnerships between forensic science and academia to facilitate step-change research. As an example of this, the Digital Forensic Science & Electronic Evidence discipline expressed the view that increased operational forensic science and academic collaboration is required to expand digital forensic capabilities aimed at criminal investigations.

However, such relations and collaborations are essentially restricted to the local environment. Furthermore, as reported by the Biological Criminalistics panel, there is often competition rather than collaboration between the universities and so multi-partner research, which would make economic sense, is problematic.

In responding to the research theme questions, as expected, the various disciplines represented adopted a discipline-specific approach. Input included the following:

- Standardisation and an evidence base is needed for the investigation of skeletal trauma [Anthropology & Archaeology].
- Research is vital to ensure that there is a basis for the opinions provided by forensic medical practitioners [Clinical Forensic Medicine & Forensic Nursing].
- There is a requirement for real-time communication networks to keep abreast of the research being conducted across each agency [Crime Scene Investigation].
- Operational forensic science and academic collaboration is required to expand digital forensic capabilities aimed at criminal investigations [Digital Forensic Science & Electronic Evidence].
- Research needs to be targeted at the skills of document examiners to apply foundational science in investigations [Document Examination].
- Continual upgrading of baseline data related to climate change is vital, particularly for estimating postmortem interval [Forensic Taphonomy & Entomology].
- We need more research on interpretation – 'what do my results mean?' [Firearms & Toolmarks].
- Improved methods of generating forensic intelligence are required, with a transitioning from traditional and rigid court reporting methods [Fires and Explosions].
- Consideration must be given to greater collaboration between forensic pathology and forensic medicine. This particularly relates to research where there should be a focus on public health and emergency medicine, considering the findings and data from autopsies to help the living [Forensic Pathology].
- With respect to research, the small number of academic forensic departments or services interested in research need to build links with each other and with related institutions including across jurisdictions [Humanitarian Forensic Science].
- The interdisciplinary nature of wildlife and environmental forensics means that research from a wide range of specialisms can yield insights for application in casework (e.g., veterinary pathology and environmental DNA (eDNA) analysis). Research networks (on a global scale) are crucial to identify foundational research gaps as well as potential new innovations to develop and validate for forensic application [Wildlife Forensics & Environmental Crime].

More generally in their submission, the Management & Quality Assurance discussion panel expressed strong support for the Sydney Declaration, which describes casework as a research-oriented activity and if a quality system does not support research, then it is not fit for purpose.

In submissions via the conference app:

- There were calls for broader, more ethnic and racially diverse databases for research and testing.
- There was also advocation for studies on forensic science learning outcomes from major miscarriages of justice.

3.4. Education and training

Three threads emerged from the discussions under this theme: (i) the importance of industry/academic partnerships; (ii) greater engagement with the legal profession; and (iii) the impact of the Sydney Declaration. The first two threads are not new.

Forensic science programs at universities boomed in the early 2000s, being heavily influenced by the popularity of television dramas such as CSI. For example, at that time in Australia, 17 universities were offering forensic science as a full or partial program [42]. Rationalisation has currently reduced that to around six ongoing programs. In the UK at the height of the boom, there were 450 tertiary courses with forensic science in the title [43].

From a forensic science perspective, the most important aspect of tertiary education programs has always been a solid grounding in science [44]. This grounding is aided by the establishment of collaboration through strong working relationships between forensic science facilities and academia, including adjunct faculty and course reference groups. These reference groups should include academics, industry partners and students to ensure that there is the correct balance between science and other critical aspects of forensic science practice. As an example, UTS has an Industry Advisory Policy [45] that sets out the requirements at their university for the establishment, management and coordination of industry and professional advisory boards and groups. Such collaboration can also provide meaningful internships, employment opportunities and cooperative research [45].

However, is such a grounding in science sufficient if one wants to favour a forensic science culture in a modern transversal expression of our discipline? The importance of this point is emphasised by Willis [46] who regards the lack of a sound foundation in forensic science as a flaw in many courses where reliance on content is based on the expertise of the lecturer rather than on educational needs or agreed principles and

definitions.

Currently, the global picture for forensic science education and training is one of heterogeneity and confusion, with little or no harmony on an international basis [47]. In this respect, the Education and Training panel advocated for a forensic science education and training network or professional association to promote collaboration, information exchange and the prevention of duplication. This panel also urged a re-think of how future generations will learn considering the global pandemic and the shift to online learning. For example, what is the correct balance between hands-on training and the use of remote/electronic presentations? Also, in addition to science and technical training skills, the panel recommended the inclusion of competencies such as critical thinking and professional ethics across all curricula. This was echoed by the Illicit Drugs & Clandestine Laboratories panel who advocated for enhancing workforce skills and competencies including technology literacy, communication and problem solving. The Clinical Forensic Medicine & Forensic Nursing panel stressed the need for retention or reintroduction of an undergraduate curriculum, and the provision of a postgraduate curriculum for the discipline. The Forensic Pathology panel identified the need to raise the profile of forensic pathology through medical schools/academia to attract more trainees (to address the global shortage of forensic pathologists) and for increased research funding. The Odontology panel called for odontology, law and ethics to be returned to undergraduate curricula and identified an ongoing need to educate and provide feedback to general dentists about the importance of the quality of their dental records. The Wildlife Forensics and Environmental Crime panel reported that forensic science, along with other mainstream science fields, needs to address issues of diversity and inclusion, and promote voices from a diverse range of backgrounds. Wildlife and environmental crime directly involve a range of non-human biological traces or environmental samples and consultation needs to be undertaken to integrate first nations knowledge and practices where appropriate.

Further examples of discipline panel submissions on this theme were as follows:

- Education and training programs are required to enable the teaching of trauma interpretation to students, which is very resource intensive. This could be enhanced by building practitioner and academic relationships and providing access for academics to trauma casework and the use of digital files and the trauma VIFM atlas, for example [Anthropology & Archaeology].
- Crime scene examiners need to have sufficient relevant knowledge/understanding to adequately exploit digital traces [Crime Scene Investigation].
- Importance of operational forensic science and academic collaboration for research and education/training [Digital Forensic Science & Electronic Evidence].
- New practitioners should be acquainted with relevant instruments of international humanitarian law, international human rights law and international criminal law. These bodies of law normally frame Humanitarian Forensic Science practice. In this light, a tertiary course should be established to provide this overview of relevant international law and associated guidelines [Humanitarian Forensic Science].
- The need to explore the complexities, challenges and opportunities more thoroughly around independence and impartiality [Science, Justice & Legal Issues].

Relevant submissions via the conference app included:

- Predictions of greater use of certified online training programs.
- Calls for a focus on competencies such a critical thinking in addition to science education and applied science training.

The second thread to emerge for this theme was greater engagement with the legal profession. In the adversarial legal environment, whether it be pre-trial conferences, the ability of legal counsel to adequately lead or challenge forensic science evidence or the judge to act as a 'gatekeeper', at least a foundational knowledge by these actors of what is to be presented by the expert witness should be expected. It is generally not the case.

As stated by the Honourable Harry T Edwards, the co-chair of the National Academy of Sciences Committee on Identifying the Needs of the Forensic Science Community, at a public hearing in 2014 [48]:

> 'The judicial system is encumbered by judges and lawyers who generally lack the scientific expertise necessary to comprehend and evaluate forensic evidence in an informed manner.'

In a similar vein, in R v Mohan [49] is the following comment:

> "Dressed up in scientific language which the jury does not easily understand and submitted through a witness of impressive antecedents, this evidence is apt to be accepted by the jury as being virtually infallible and as having more weight than it deserves."

Further, Black and Nic Daeid [50] state that:

> "Both the scientist and the court have a duty to ensure that each party does their utmost to ensure that the jury understands the capabilities and limitations of any science presented to them. The scientists must be able to convey their often-complex subject as simply as possible. Only then will the lawyers and judge be able to guide the jury to reach a secure and informed decision."

Casella and McCartney [51] report that it has become increasingly common for calls to be made for forensic scientists and legal professionals to end their 'dialogue of the deaf' and to communicate more effectively at least on basic principles, vernacular, and nomenclature of both science and law, as well as the working practices and customs of each group of practitioners. However, there are few attempts to identify those who will ensure that this understanding is acquired. Hackman [52] also addressed the importance of communication and noted that there is much work to be done in fully unpicking and understanding how challenges related to clear communication can be met to ensure that forensic science is accurately represented at all stages of the criminal justice process. The National Research Council (USA) [53] suggested that, in the long term, the best way to get lawyers and judges up to speed is for law schools to offer better courses in forensic science in their curricula. However, with the rapidly growing knowledge gap between forensic science and the law (and the general public), resulting from digital transformation and new technologies, it is highly questionable whether such a suggestion is viable.

Along similar lines, the Science, Justice & Legal Issues panel reported that the use of AI and other cutting-edge technology poses challenges for clear communication by forensic science practitioners. However, such communication is essential to meaningfully assist the court, particularly when the technology is contributing to the expert opinion. Therefore, there is an ongoing need for improved communication and cross educational opportunities between science and legal practitioners. Through the conference app, there were calls for more multi-disciplinary forums and a greater willingness by lawyers and judges to engage in such forums.

With respect to the third thread in the education and training theme, the Sydney Declaration, Jennifer Raymond in her presentation for the SD seminar stated that the Declaration should be used as a sense check for existing operational forensic science facilities and a benchmark for new disciplines and evolving agencies and capabilities. It should be embedded in academic forensic science programs and imported by students into employing organisations. Similarly, Nicholas Cowdery acknowledged that the Sydney Declaration recognises the interaction between the law and science and the fact that context is all important. Furthermore, legal academics need to include the SD in their curricula, judges need to recognise its value, and then lawyers need to support and

promote it. Rebecca Bucht in her WTFH plenary presentation said that, given the support for the principles of the Sydney Declaration within the forensic science community, informative discussions should be held with stakeholders and end users to ensure that there is a shared understanding of what forensic science is and what it can and cannot do. The Military Forensic Science & Counterterrorism panel were of the view that non-traditional forensic science organizations should review and (where appropriate) implement the Sydney Declaration.

3.5. Culture and professionalisation

Throughout this paper, there is consistent narrative about the need for a specific forensic science culture. Organisational culture has been defined as:

> *The collection of values, expectations, and practices that guide and inform the* actions of all team members. [54]

From the authors' perspective, the values, expectations and practices within forensic science are internationally ill-defined and there needs to be a focus on research, education and training, the Sydney Declaration, and a collective voice to establish and nurture a global culture.

In mentioning the growing consensus that there is a crisis in forensic science at a global scale, Morgan [55] highlighted that there is a need for a consensus on what forensic science is and what it is for. She calls for a consistent and cogent authority that is developed collaboratively and accepted across the entire justice system to identify the different elements and to articulate effective solutions for current challenges.

Specifically, Morgan refers to global scrutiny and key reports including from the National Academy of Science [3], annual reports from the Forensic Science Regulator, the US PCAST report [4], successive UK House of Commons Science and Technology Committee reports, and the House of Lords Science and Technology Select Committee report [56]. She states that there is consensus across the various reports that 'profound changes to funding and governance are required to ensure that forensic science survives and begins to flourish rather than lurching from crisis to crisis'.

That begs the question: what has changed? The answer is very little in terms of both funding and governance.

Weyermann and Roux [14] argue that forensic science may not be faced by just one crisis, but several overlapping issues and challenges highly dependent on the contexts in which forensic science is applied. This suggests that funding and governance alone will not address this overarching challenge. As a possible way forward, Weyerman and Roux propose to consider a balance between (i) a solid core of unifying forensic science concepts and principles focused on the concept of trace, (ii) appropriate (iterative abductive and deductive) reasoning, and (iii) flexibility to adapt to the large variety of purposes in different politico-legal systems using a variety of evolving experimental tools.

Examples of exceptions to funding are the European Network of Forensic Science Institute's (ENFSI) engagement with the European Commission (EC) [57]. This relationship has resulted in ENFSI receiving funding for cross-border forensic science initiatives on an annual basis. In the USA, the National Institute of Standards and Technology (NIST) funds the Organization Of Scientific Area Committees For Forensic Science (OSAC) to produce standards for most of the forensic science disciplines [58].

A significant change with respect to culture and professionalisation is the development and publication of the Sydney Declaration [11] with its definition and principles of forensic science bringing with it a sense of identity. Bucht et al. [59] explained that the Declaration is about reclaiming forensic science and refocusing on its foundation, which includes the articulation of a shared understanding and broad acceptance of its essence, purpose, and fundamental principles.

The Management & Quality Assurance panel called for the embedding of a culture, not just around quality itself, but in general around continuous improvement, innovation, and identifying diverse ways to do things. This includes diversity of thought, creativity and individual responsibility, which is in total contrast to the blame culture that tends to permeate an adversarial system.

In his presentation for the WTFH plenary session, Pierre Margot called for scientists to make their voice heard and to take leading positions so that forensic science can become a driving force in influencing the development of science-based investigations. This is a much-needed challenge to the culture of forensic science and its predisposition to silence. In relation to finding a voice, Linzi Wilson-Wide in her presentation for the WTFH plenary session, stressed the importance of controlling the narrative and countering social media 'fake news'. In the same session, Rebecca Bucht advocated for calling out unethical behaviour and poor practice, and Jason Payne-James highlighted the need for an explanation and promotion of forensic science, human rights, ethics and AI. Sheila Willis stated that forensic scientists needed to be more courageous, to stand up and be counted rather than hide behind standard operating procedures. She further emphasised that there is a chronic need for leaders in the field.

Where is the foundation for such a voice? James Robertson in his award presentation pointed out that forensic science has no professional body to accept that role and, therefore, no channel to offer a counter narrative, for example. There is clearly a call for enhanced forensic science leadership globally.

Several submissions made in relation to WTFH advocated a more socially aware role for forensic science as a cultural plank. Examples include the following:

In his presentation at the Sydney Declaration Seminar, Noel Woodford raised the question about what we are doing to correct the significant 'inequality of arms' between well-resourced and publicly funded forensic science organisations and resources available to the defence. Linzi Wilson-Wide in her presentation to the WTFH Plenary, identified the requirement for a psychologically safe environment that promotes innovation and attracts and retains promising scientists particularly in an era of multiple careers for the younger generation. Jason Payne James in his presentation to the WTFH Plenary advocated an increased role for forensic science in geopolitical instability and international criminality such as gender-based violence and the importance of public engagement related to our role. Such engagement must be accompanied by communication with and education of politicians regarding the huge societal relevance and implications of our work.

The Illicit Drugs Panel encouraged participation in safer communities by informing legislative reform, providing early health warnings (cosmos project) and countering illicit pharmaceuticals. The Science and Justice Panel asked how are the forensic sciences learning from wrongful convictions, being proactive and responding to reduce the likelihood of similar occurrences in the future? For example, advocating the establishment of Criminal Case Review Commissions (CCRC) or similar as occurs in the UK, Canada and New Zealand)

What are the obstacles on the way to addressing the global crisis as described by Morgan [55] and the current culture of silence?

In the WTFH plenary session, Simon Walsh (Chair) and Rebecca Bucht raised the issue of 'barnacles on the boat' slowing progress. Stated impediments included:

- not calling out unethical and unprofessional behaviour
- not making space for, arguably, the more tech savvy new generation
- operational and academic environments that do not encourage emerging forensic scientists
- overloaded/over-engineered quality management systems that stifle independent and critical thinking and
- foundational standards (e.g., ISO17025) that seemingly are not fit for purpose [37].

Many of the other points discussed under this theme could well be included in the 'barnacle' category and we could add issues raised under other themes including the paucity of research on forensic science

practice, heterogeneity/confusion in the education and training space and the lack of a defined culture.

3.6. Practice, skills and competencies

3.6.1. Practice

The practice of forensic science can and has been depicted in many ways. Essentially it is a continuum and one depiction is provided in Fig. 1.

To a large extent, this depiction reflects the definition of forensic science as highlighted in the Sydney Declaration [11]:

> *"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)."*

The Sydney Declaration has seven fundamental principles and, in his presentation for the SD seminar, Keith Inman referred to Principle 2:

> "Scene investigation is a scientific and diagnostic endeavour requiring scientific expertise."

He went on to say that the typical view of the role of the scene of crime officer (SOCO) has historically been to search for and collect/preserve physical evidence (traces) associated with the event under investigation. The common notion of crime scene investigation being a "document, search, and collect" exercise with reconstruction of sub-events (e.g., blood trails, point of entry, directions for footwear marks and bullet trajectories) is much too limited.

The latter point was reiterated by Sheila Willis in her presentation for the SD seminar:

> "The key role of traces as vectors of information arise at the scene and this needs to stay as a centre focus so that we avoid a bag and tag approach and be mindful of what questions we are trying to address."

Returning to the presentation of Keith Inman, he stressed that it is essential that crime scene personnel, from the first moments of the investigation, begin to pose as many reasonable alternate explanations for the origin (source and activity) of any traces deemed to be of interest, as well as to adjust the search strategies according to both the context of the event and the reasonable explanations. That knowledge of all of the processes of a scientific investigation, from crime discovery to final interpretation, are required at the crime scene in order to derive a final interpretation that properly assesses the uncertainty of the many traces in the context of the event. Both Inman and Willis underlined the criticality of the scientific approach to the practice of crime scene investigation as the first step in the forensic science continuum.

In a further reference to forensic science practice and the Sydney Declaration, Noel Woodford in his SD seminar presentation reported that, in relation to the fundamental principles, forensic medicine is certainly case-based, its opinions are reliant on reasoning, it is reconstructive (the 'what happened' specialism, where ground truth is most often not known or knowable), it operates in areas of uncertainty, and it is very context dependent. He further reported that a 'body' or part thereof could reasonably be construed as a 'trace' and, as a consequence, the field of forensic medicine/pathology would certainly fall within the ambit of the declaration.

In relation to practice, the Management & Quality Assurance panel welcomed the challenge to traditional thinking around how we approach quality. This included ideas around risk management and a risk lens being applied to quality. The panel reported that quality needs to continuously improve, with the requirement to move quality in the direction that forensic science requires. Whatever the direction, quality systems should not be so rigid as to stop people experimenting in the realisation that a particular case might require a different approach. The panel also stated that a mountain of documentation does not equal effectiveness.

In his presentation for the WTFH plenary session, Dean Catoggio stressed that integration of digital and natural (physical) forensic sciences at triage is required to ensure a holistic answer to customer questions and best value for end users. With respect to the role of triage in forensic science practice, the Biological Criminalistics discussion panel highlighted presentations during the conference related to developing a trans-disciplinary evidence recovery model and the creation of unified laboratory spaces with different forensic groups collaborating in a multidisciplinary environment. These models were described as having a holistic evidence recovery mindset, providing the opportunity for cross-skilled scientists to evaluate traces within the context of the case and apply the most appropriate techniques in the best order of examination to maximise evidence recovery.

The Humanitarian Forensic Science discussion panel reported a poor level of development globally of relevant forensic infrastructure, especially those related to medico-legal death investigations. Capacity and capability are generally weak, and the international institutional landscape is sparse. Opportunities to engage in the field are extremely limited and mentorship or pathways for interested practitioners to follow to become involved are also limited. In building capacity, there is a need for community engagement to ensure that cultural and religious sensitivities are understood and integrated into any operational response.

The issues of evaluative and activity reporting were raised by several discipline panels and by a number of individuals. For example:

- The Firearms & Toolmarks panel reported that education and training should extend to evaluative reporting.
- The Science, Justice & Legal Issues panel underlined the importance of interdisciplinary opportunities for learning about activity level reporting (e.g., the nature of the activities at the crime scene).
- Dean Catoggio in his presentation for the WTFH plenary session advocated for the balance and transparency brought about by evaluative reporting becoming more widespread across all disciplines.
- Sheila Willis in her presentation for the SD seminar gave an example of activity level reporting as incorporating multiple traces such as DNA and glass from a single criminal event. She went on to say that addressing activity level propositions is more likely to provide the decision maker with useful information; however, this is sometimes seen as being too difficult or based on poorer-quality data. She therefore advocated for further research to address useful questions.

3.6.2. Competencies

Neuteboom et al. [37] reported findings from a recent survey targeting directors and senior managers, including quality managers, of

Fig. 1. An example of a schematic for forensic science practice.

forensic science laboratories/facilities. The findings included:

- a lack of agreement on the core cognitive competencies required for working in forensic science;
- a lack of identification of many competencies, particularly cognitive competencies, and, therefore, they are not routinely assessed or monitored; and
- tools regularly used in forensic science to assess the maintenance of competencies (e.g., proficiency tests, case record peer review, and audits) are not necessarily designed to assess cognitive competencies.

Regarding the proper use of competencies, Kelty et al. [60] stated:

'With recruitment and training done well, organizations are better placed to attract, develop, and retain personnel with potential to excel in complex roles'.

In follow-up research, Neuteboom et al. [61] are planning to identify what the forensic science community believes are the core cognitive competencies and attributes required for forensic science professionals.

Competencies were also raised on several occasions throughout the conference:

- In her presentation for the WTFH plenary, Caroline Gibb advocated for better coordination of our actions to ensure best practice approaches are being taught, championed, supported, and operationalised throughout the industry. Practitioner competency must encompass theoretical knowledge, practical skills, professional attitude, and controlled experience.
- The Illicit Drugs & Clandestine Laboratories panel reported the need to enhance workforce skills and competencies, including technology literacy, communication and problem solving.

4. Summary and concluding comments

There is no doubt that there were many positives to come from IAFS 2023. The fact that it was the first full IAFS conference since Toronto in 2017 was one of them. It brought the opportunity for the renewal of existing friendships and partnerships, and the formation of new ones. Importantly, as expressed by one of the plenary speakers, IAFS 2023 served as a pivotal moment where forensic science began articulating its own language and championing its distinctive culture and vision. In the view of the authors this is a key message which should be rigorously pursued by, for example, advocation and promotion of the Sydney Declaration [11].

The conference and the Where to from Here strategic discussions emphasised several key challenges that all come with opportunities. These topics are:

- Digital transformation

Digital transformation is inevitable. It will only continue, if not increase, in size, variability and speed. It will increasingly influence, impact, and inform all aspects of the forensic science landscape. It should therefore be embraced by the forensic science community.

- Integration and harmonisation

There are enormous benefits to be gained by the integration of outputs of currently disparate forensic science disciplines, of research and education and training which are largely uncoordinated and fragmented pursuits, certainly internationally and of standards for data management and sharing. There is also a role here for bridging the ever-increasing knowledge gap between forensic science and its end-users (e.g., policing and the legal profession).

- Forensic science and its social responsibility

Forensic science has an important and increasing social responsibility. Examples include partnerships in the investigations of human right violations, geopolitical instability and international criminality such as gender-based violence, participation in safer communities by informing legislative reform and being proactive in supporting a reduction of wrongful convictions.

- Finding a voice

Forensic science lacks a unified voice primarily because it is often viewed as a collection of separate disciplines rather than a distinct, cohesive domain. It lacks a genuine professional body to represent it. It neither addresses unethical behaviour and poor practices nor defends itself against unjust criticism. It lacks prominent and effective leadership in this space.

As stated by Pierre Margot:

'Scientists must make their voices heard and take leading positions so that forensic science can become a driving force in influencing the development of science-based investigations'.

In terms of WTFH, an effective response can only come from the forensic science community itself. Endless inquiries and commissions, perhaps well meaning, have not led to any strategic follow-up, forward planning or ongoing commitment from the authorities who instigate such inquiries/commissions. Little advancement can be expected under these circumstances. What is required is a critical cultural shift across the whole forensic science landscape and resolute and visionary leadership if we are to successfully address these challenges.

The required cultural shift can only happen through education and an appropriately organised and supporting system. It will not occur overnight as it will primarily succeed through the percolation of tomorrow's leaders. However, in the authors' opinion, a vital first step in this change process is to promote a more universally shared view of forensic science being a context-based and problem-solving discipline primarily interested in the recognition, exploitation and interpretation of event traces (signs or remnants); i.e., 'the science of the trace' [62–65]. Current and next-generation leaders across the forensic science community will need to collaborate on the development and implementation of strategies to tackle the challenges and opportunities identified in this paper. The Sydney Declaration [11] and other guiding documents, for example [66], will undoubtedly help them in this endeavour.

CRediT authorship contribution statement

Chris Lennard: Writing – review & editing, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Alastair Ross:** Writing – review & editing, Writing – original draft, Validation, Project administration, Methodology, Investigation, Conceptualization. **Claude Roux:** Writing – review & editing, Validation, Methodology, Formal analysis, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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APPENDIX 1

Themes and questions

Theme 1 – Integration and Harmonisation

Key Question(s)

- What initiatives are currently in place within our discipline for a *holistic approach* to:
  - o casework (e.g., triage);
  - o integration of our discipline (e.g., direct engagement and sharing results/data) with other disciplines;
  - o assessment of casework data (including from other disciplines) to assess trends, link cases, and provide intelligence.

- What initiatives are currently in place within our discipline for a focus on policing and security issues (including crime disruption, crime prevention and forensic intelligence) in addition to the courts?

Theme 2 – Digital Transformation

Key Question(s)

Is digital transformation impacting our discipline? If so, how?

Theme 3 – Research

Key Question(s)

What are the 2 most pressing research needs in our discipline?

Theme 4 – Education and Training

Key Question(s)

Are there valid criticisms of your discipline that need to be addressed through targeted education and training?

How will education/training in your field need to evolve in the future?

Theme 5 – Technology

Key Question(s)

What, if any, current/emerging technology will have a significant impact on your discipline (either technology used by criminals or technology available for forensic use)?

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