

# Northumbria Research Link

Citation: Amankwaa, Aaron, Amoako, Emmanuel, Mensah Bonsu, Dan Osei and Banyeh, Moses (2019) Forensic science in Ghana: A review. Forensic Science International: Synergy, 1. pp. 151-160. ISSN 2589-871X

Published by: Elsevier

URL: <https://doi.org/10.1016/j.fsisyn.2019.07.008> <<https://doi.org/10.1016/j.fsisyn.2019.07.008>>

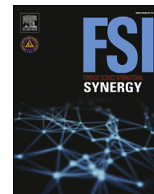
This version was downloaded from Northumbria Research Link:  
<http://nrl.northumbria.ac.uk/id/eprint/40226/>

Northumbria University has developed Northumbria Research Link (NRL) to enable users to access the University's research output. Copyright © and moral rights for items on NRL are retained by the individual author(s) and/or other copyright owners. Single copies of full items can be reproduced, displayed or performed, and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided the authors, title and full bibliographic details are given, as well as a hyperlink and/or URL to the original metadata page. The content must not be changed in any way. Full items must not be sold commercially in any format or medium without formal permission of the copyright holder. The full policy is available online: <http://nrl.northumbria.ac.uk/policies.html>

This document may differ from the final, published version of the research and has been made available online in accordance with publisher policies. To read and/or cite from the published version of the research, please visit the publisher's website (a subscription may be required.)



**Northumbria**  
**University**  
NEWCASTLE



## Forensic science in Ghana: A review

Aaron O. Amankwaa<sup>a,\*</sup>, Emmanuel Nsiah Amoako<sup>a</sup>, Dan Osei Mensah Bonsu<sup>b,c</sup>,  
Moses Banyeh<sup>d,\*\*</sup>



<sup>a</sup> Science & Justice RIG, School of Law, Northumbria University, Newcastle Upon Tyne, UK

<sup>b</sup> Forensics Research Group, Australian Centre for Ancient DNA (ACAD), University of Adelaide, Adelaide, Australia

<sup>c</sup> Department of Forensic Sciences, University of Cape Coast, Cape Coast, Ghana

<sup>d</sup> Department of Biomedical Laboratory Science, University for Development Studies, Tamale, Ghana

### ARTICLE INFO

#### Article history:

Received 8 July 2019

Received in revised form

22 July 2019

Accepted 23 July 2019

Available online 30 July 2019

#### Keywords:

Forensic science

Policy

Legislation

Governance

Impact

Education

Ghana

### ABSTRACT

The use of forensic science continues to grow across the world. In Ghana, major advancements took off in 2011, including the introduction of modern DNA profiling and the establishment of an automated fingerprint identification system. These developments have led to some positive impacts on the delivery of justice, including the exoneration of a wrongly incarcerated individual. However, a review of the policy-related aspects of forensic science shows gaps in legislation, governance, service provision, quality assurance and accreditation, education and research. An important recommendation to improve forensic science in Ghana is the creation of a “national policy strategy”, a blueprint informed by relevant stakeholders, best practice from other countries and the status of the field. Resolutions to the policy issues identified in this review will ensure a more robust application of forensic science in delivering safe justice and enhancing public security.

© 2019 The Author(s). Published by Elsevier B.V. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

## 1. Introduction

Forensic science is the application of science in answering questions of legal importance. It is an interdisciplinary field comprising different subject areas, actors and organisations across scientific and legal disciplines. Devoted to the administration of safe justice, forensic science plays a crucial role in the criminal justice system (CJS). It can assist law enforcement authorities and the courts in the resolution of crime by facilitating the identification and apprehension of crime perpetrators. The use of forensic science involves a wide array of activities ranging from crime scene evidence gathering, developing investigative strategies, generating investigative leads through different lines of inquiry, and the processing of evidential materials that are of probative value in a relevant case. The different dimensions in which forensic science can be used present several complexities that impact its value

within the legal system [1].

Forensic science uses several scientific, technological and technical applications. The most common of these are fingerprint and finger-mark analysis, DNA testing, firearm and tool mark examination, drugs and toxicological analysis, and forensic pathological analysis. Modern or new forensic science applications include facial comparison, video and audio analysis, digital forensics and new technologies that improve upon the traditional forensic applications. Efforts to consolidate the benefits of forensic science have improved globally [2], with an increasing trend in cross-border collaborations through the transnational exchange of forensic data [3]. However, harnessing the capabilities of forensic science comes with the costs of establishing laboratories, training personnel, and developing appropriate policies and systems for quality control and assurance. These costs, inevitably, present difficulties in pursuing forensic science and its usage may be limited to the availability of sufficient funds [4]. This may be more pronounced in developing countries.

The use of forensic science is recognised in Ghana's adversarial criminal justice and civil systems. The Forensic Science Laboratory (FSL), a division under the Criminal Investigation Department (CID) of the Ghana Police Service (GPS), serves as the main provider of

\* Corresponding author.

\*\* Corresponding author.

E-mail addresses: [aaron.amankwaa@northumbria.ac.uk](mailto:aaron.amankwaa@northumbria.ac.uk) (A.O. Amankwaa), [emmanuel.amoako@northumbria.ac.uk](mailto:emmanuel.amoako@northumbria.ac.uk) (E. Nsiah Amoako), [danoseimensah.bonsu@adelaide.edu.au](mailto:danoseimensah.bonsu@adelaide.edu.au) (D.O. Mensah Bonsu), [mbanyeh@uds.edu.gh](mailto:mbanyeh@uds.edu.gh) (M. Banyeh).

forensic science services to law enforcement agencies across the country. With a history since 1948, the FSL has grown both in infrastructure and scope of forensic science capabilities [5]. In 2011, the FSL was refurbished under the European Union – Ghana Police Project flagship programme with a £3 million funding [6]. The scope of services provided by the laboratory are covered under the sections of Chemistry and Drug Analysis, Ballistic and Firearms, Document Examination, Photography, and DNA analysis [5]. The FSL aims to provide quality scientific analysis to private and public institutions in Ghana and other neighbouring countries in the sub-Saharan region, as well as to strengthen criminal investigations with timely and cost-effective services [6].

There is currently limited information about the technical operation and performance of the FSL in the public domain. A review of information from several media sources suggests that the FSL may be functioning below its capacity. For instance, the refurbishment of the laboratory in 2011 was regarded as a step forward in obtaining and maintaining international accreditation [7]. Notwithstanding, this milestone has not been achieved and the forensic science field is challenged with a limited number of qualified experts [8] and frequent media reports of tampered evidence [9]. The root cause of the challenges in forensic science provision is complex and overlaps in areas of funding and resources, management and governance, and policy, which imply a low-priority status for forensic science in Ghana.

Characteristic of other developing countries, crimes such as trafficking of illicit drugs, armed robbery, kidnappings, sexual and violent offences, cybercrime and arson-linked fire outbreaks are not uncommon in Ghana. These crimes presuppose the need for integration of varied innovative forms of crime-solving capabilities into traditional policing operations. Whilst the police continue to receive support in areas of traditional policing [10], capacity building in forensic science is low. This may partly be due to an inadequate appreciation of forensic science as the police rely mainly on public intelligence, tip-offs and witness/suspect interrogations during criminal investigations. The effects of these are evident, with a lack of professionalism in physical/forensic evidence collection and management, and gaps in investigative leads. Sometimes, confiscated drugs evade tracking and possession from law enforcement custody [11,12]. Further, high-profile cases with potential forensic interest continue to make headlines, including rape cases, murder and kidnapping involving local and foreign nationals [13,14]. The investigation of these cases is often met with difficulties of needless delays, poor crime scene management and evidence handling, and sometimes the outcome of investigations are unknown.

As a pivot of forensic science, a sound policy ensures that forensic science is delivered in a context that assures justice and identifies and protect against miscarriages of justice. This paper responds to the poor and under-utilisation of forensic science in Ghana by analysing the key policy-related issues of forensic science service provision. The overall aim of the review is to provide relevant recommendations for change based on current international “best practice”. The paper provides a foundation that could assist policymakers in developing appropriate policies to govern forensic science and maximise its utility. The key areas of forensic science provision that are scrutinised in this paper are legislation, governance framework, forensic science service provision, quality assurance and control, impact on the criminal justice system, forensic science education, and research and development. In summary, the review identifies gaps in areas such as legislation governing forensic biometrics and expert witness testimony, leadership for forensic science, funding and investment and quality standards for forensic science.

## 2. Forensic science legislation

The investigative and intelligence function of law enforcement agencies is established by law. In Ghana, the supreme law from which law enforcement agencies derive their powers is the 1992 Constitution [15]. This provides the scope of their powers to investigate crime and the basic rights of individuals under investigation and/or prosecution. Chapter 5 of the Constitution defines the fundamental human rights and freedoms of individuals. Two principal rights linked to the investigation of crime are Articles 18 and 19, which cover the right to privacy of individuals and the right to a fair hearing, respectively. Article 18 (2) upholds the principle of proportionality and necessity in any interference with the right to privacy. This restricts the powers of law enforcement agencies and other authorities in the collection, retention and use of investigative material and/or information from individuals (For example, see *Cubagee v Asare and Others* 2018 [16]). Article 19 encompasses the “fair” management and disclosure of evidence in criminal cases, which can have an impact on the actual hearing by a court. In effect, the processing and use of evidence, including forensic evidence, must be legal, legitimate, proportionate, necessary and transparent.

In addition to the Constitution, there is specific legislation that layout the powers of law enforcement agencies in gathering evidence or information during investigations and the admissibility of evidence. The Criminal and Other Offences (Procedures) Act 1960 (Act 30) details the procedures for arrest and detention, treatment of suspected individuals, and search and seizure of evidence [17]. The Act allows the police to search and recover any items on an arrested person or premises that may be material to a suspected or alleged offence. In the case of arrestees, the law prohibits the examination of the private person by officers (section 8). Act 30 also specifies the regulation of information or evidence that may be used at trial including scientific reports (section 121). The law generally allows the courts to only admit into evidence the reports or testimony of “Scientific Analysts” recognised by the Minister for Justice by “notification published in the Gazette”.

Another important legislation is the Evidence Act 1975 which defines evidence as “testimony, writings, material objects, or other things presented to the senses that are offered to prove the existence or non-existence of a fact” (Section179) [18]. The principal test for the collection of biological samples (i.e. body fluids or substances); information about physical features, physical and mental health; and data about behavioural characteristics is the necessity of these in the relevant issue. This test is subject to the discretion of the courts and individuals cannot refuse such sampling (Sections 96 and 97). The primary test of admissibility of evidence (such as forensic evidence) is relevance, which is also subject to court discretion (Sections 51 and 52 of Evidence Act). Further, Section 51 (2) of the Evidence Act states that “all relevant evidence is admissible except as otherwise provided by any enactment”. Relevant evidence may be excluded if it is outweighed by other competing interests including the risk of unfair hearing or verdict, which is consistent with the 1992 Constitution [15].

According to the Evidence Act, a court expert may be called upon to provide an expert opinion within their subject of expertise or qualification (sections 67 and 112–115). The expert testimony is required to be of assistance to the court in understanding the evidence or facts in a legal issue. These rules are consistent with the common law admissibility (CLA) tests of assistance and relevant expertise in England and Wales [19]. Based on section 113 of the Evidence Act, an expert witness is not required to disclose the basis of their opinion before presenting their testimony. Further, the basis of the expert opinion ‘need not be admissible in evidence’ although these may be examined by the court or the parties to the case. The above rules may be incompatible with the tests of

impartiality and evidentiary reliability, which are upheld as part of the CLA test and Daubert Standard [20,21]. Internationally, there is a wide consensus to ensure transparency in forensic reporting and reliability, including balanced, logical and robust presentation of evidence [22]. This means a reform of the Evidence Act may be required. Another area of concern is the rule about expert opinion on “the ultimate issue”. Section 115 of the Evidence Act suggests that expert opinion that borders on the ultimate issue to be determined by the trier of facts may be admissible. Expert opinion on the ultimate issue is generally considered to be inadmissible due to their potential to mislead the trier of fact or the jury [23,24]. The current admissibility framework in Ghana may pose a risk to the safe delivery of justice. Hence, a reform of the current law on forensic expert witnesses and evidence reporting may be necessary to comply with international standards.

Presently, Ghana lacks national forensic information databases such as a national DNA and fingerprint database for criminal investigation/intelligence purposes. The 2016 Interpol Global DNA Profiling Survey found that Ghana holds 1,193 DNA profiles [25]. Of these, 202 are from known individuals, 338 are from crime scenes, 3 from missing persons, 1 from relatives of missing persons, 1 from unidentified human remains and 648 other profiles. The Data Protection Act 2012 (DPA) classifies DNA data as a “special personal data” that can only be processed when necessary or where the individual gives their consent (section 37) [26]. The use of fingerprints has been a core part of police activities in Ghana (formerly Gold Coast) since 1922 [6]. The total number of fingerprint records held for policing purposes is not publicly known. In September 2011, the CID implemented an automated fingerprint identification system (AFIS) which holds more than 3,700 records of convicted individuals [27]. The CID plans to include all manual records of convicted individuals in the AFIS database. The existing law allows for the collection of DNA and other biometric information under the discretion of the court when necessary. There are no specific laws to govern the inclusion and retention of forensic biometric information in a database after the conclusion of an inquiry or proceedings. This gap may have both public security (such as failure to solve a crime) and human right implications (breach of privacy), and an urgent adoption of specific forensic biometric legislation is necessary to enhance the effectiveness and legitimacy of forensic science in Ghana.

### 3. Governance framework

As stated earlier, the major provider of forensic science services in Ghana is the GPS CID FSL. The GPS is headed by the Inspector General of Police (IGP), who is appointed by the President of Ghana. The IGP is responsible for the operation of the GPS and administers the service with the support of directors of several departments including the CID. The GPS is one of the agencies of the Ministry of Interior (MOI), which provides policy guidance and standards. The main statutory oversight body for the GPS is the 10-member Police Council which is made up of the Vice President as chairman, stakeholders within the Executive and Judiciary arms of Government and the CJS, and appointees of the President (section 201 of the Constitution) [15]. There are limited specific policy guidance or standards for forensic science from the MOI or the Police Council, and the current governance framework could be described as a police-led system. This orientation may be prosecution biased and may have an adverse impact on the application of forensics in the CJS [28,29].

One of the aims of forensic science is objectivity, and this has been recognised as an essential consideration in the institutional structure for forensic providers [28]. In Scotland, for example, forensic science is managed under the Scottish Police Authority

(SPA), which is independent of the Scottish Police Service [30]. This governance framework (i.e. institutional independence) is considered to provide more independence and impartiality in forensic investigations [31]. Another governance model is the England and Wales system which provides a good level of transparency and independence in the governance of forensics. A unique feature of this framework is the establishment of an independent Forensic Science Regulator (FSR) that provides guidelines on the quality of forensic services. The mandate of the FSR includes setting quality standards that are consistent with international standards. The FSR is also responsible for investigating quality failures, producing codes of practice and conduct, and ensuring compliance [32]. Although the forensic market in England and Wales is mixed (includes both police and private providers) [33], the role of the FSR allows for consistency in forensic science practice and service quality across a wider marketplace. It is worth noting that the governance frameworks in the UK have their roots in miscarriages of justice and distrust of the police [31]. Boateng and Darko [34] highlight a considerable distrust between the GPS and the public. This may be influenced by public perceptions of the police as a corrupt institution [35]. In consideration of the above, a possible improvement to the governance of forensic science in Ghana could be a transfer of the FSL from the direct command of the GPS to an independent body such as the MOI or the Ministry of Justice or a newly formed public body. Alternatively, an independent Forensic Science Regulator or Oversight Body could be established to govern forensic science service provision. This clear leadership structure could enhance the utilisation of forensic science and maintain public confidence and transparency in its application.

### 4. Forensic science service provision

Against the backdrop of the legal and governance context detailed above, this section reviews the provision of forensic services in Ghana. The approach of forensic science service provision varies across jurisdictions. With law enforcement agencies being the primary customers, forensic science services are mostly provided by state-owned forensic science laboratories, with few exceptions such as in the UK where a commercialised private sector exists. In Ghana, both a monopoly and a monopsony system of service provision exist where the police service is the largest provider and user of forensic science services. Other forensic services are provided by state institutions, hospitals and private organisations such as E-Crime Bureau [6,36]. Some specialised disciplines, such as analysis of controlled substances, is also carried out by the Ghana Narcotics Control Board. Adequate information about the caseload of the FSL is not publicly disclosed. However, the commonly reported areas of forensics in the media are drug testing and DNA analysis in civil paternity testing, with a handful of opportunities for serious crime investigations and immigration-related disputes. According to the GPS website [5], the chemistry and drugs analysis section of the FSL examines an average number of 800 cases of confiscated drug samples per year. In addition to providing forensic services to the police, the FSL operates a fee-for-service to the public and the court. For instance, document examinations for civil cases are provided at a fee of GH¢1000 (~\$185) while the DNA section charges a fee of at least GH¢1500 (\$277) for DNA analysis for relationship testing [5]. These charges are reported to generate funds for the State.

The outlook of crime history, statistics of crime and recent high-profile cases in Ghana suggest a positive prospect for forensic science. However, the underutilisation of forensic science may contradict this perspective. This challenge may be due to inadequate resourcing and funding of forensic science across the country. In fact, forensic science is considered an expensive enterprise in

terms of facilities, equipping and staffing of laboratory, quality management systems and training of scientists. Even in countries with advanced forensic capabilities, resourcing and funding of forensic science are problematic and the need for spending on forensic science must be justified. The demographic characteristics of a jurisdiction, crime levels and availability of funding are considered as some of the critical issues for justification of spending on forensic science [4].

In Ghana, regardless of the importance of forensic science in criminal justice, spending on forensic science competes with other social amenities and other agencies within the CJS. However, for the safety of society, equal attention to forensic science should be a genuine concern. Although the FSL received a facelift in 2011,<sup>1</sup> its capacity to meet all the demand for forensics across the 16 regions of Ghana is limited. The FSL is located in Accra, the capital city of Ghana, hence other regions of the country may not receive adequate scientific support in a timely manner. This highlights a need to establish forensic facilities or units across other regions of Ghana whilst sustaining the development of the central FSL in Accra. The refurbishment of the FSL was, partly, in response to some expensive cost of criminal investigations where evidential samples had to be taken to other jurisdictions for forensic analysis, with the extra cost of airfare and risks to the integrity of evidential materials. This risk may still exist without a sustainable decentralisation strategy for forensic science across Ghana. One approach of ensuring decentralisation, as well as improving the resourcing of forensic science, could be through regulated public-private partnerships, collaboration with university laboratories and hospitals. This approach will promote the development of the central FSL as a national lab, and the creation of regional forensic units.

Without the necessary funding for forensic science, delays in criminal proceedings, abbreviated and biased forensic investigation, and unresolved crimes would always pose a threat to the administration of justice in Ghana. Through an independent leadership framework (section 4), the provision of forensic services could be improved nationally through a sustainable funding and grant scheme. For example, even though the demand for forensic science may be driven by police forensic needs, direct funding may come from an institution such as the Ministry of Justice and Attorney General's Department (MOJAGD) through its high bargaining power for adequate government funding to support forensic science provision for both prosecution and defence. In the US, the Department of Justice through the National Institute of Justice provides funding for forensic science practice and research for federal, state and local forensic science laboratories [37]. Such funding arrangement is also desired for forensic science practice in the UK [38].

Another additional scheme to sustain and develop the forensic science market could be based on the East Midlands Special Operations Unit – Forensic Services (EMSOU – FS) system in the UK. For this approach, forensic science and investigation service are provided on behalf of five police forces of the East Midlands region from a combined forensic science unit. Funding is shared across all collaborating police forces in an agreement. Financial contribution is calculated in accordance with apportionment ratios proportional to the operational policing grant of each collaborating force [39]. The advantages of this system include cost-effective and timely

deployment of forensic science for criminal investigation. In Ghana, similar arrangements could be established by police stations in the same region or district. The financial contribution could be based on specifications, such as the size of policing area and individual forensic science needs. The combined forensic unit would provide analytical services for all the police stations in the collaboration. This approach will reduce the burden on the current central FSL, allowing the unit to operate at the national level and focus on the development of national forensic capabilities such as the creation and operation of national forensic information databases (DNA, fingerprints, footwear marks and others) and national research to support forensic science. Further, funding from police forces would be a relatively easier approach, which will complement direct funding from a dedicated national organisation or public department such as the MOJAGD.

## 5. Quality assurance, accreditation and regulation

The justice system in which forensic science operates is expected to maintain a zero tolerance of errors as the consequences of error can be grievous [40]. Moreover, forensic science labs are also regarded as high-risk organisations where any error carries a high possibility of causing harm [41]. Any errors can result in miscarriages of justice or 'near-misses', which can also lead to public distrust in forensic science and the legal system. To avoid miscarriages of justice, there is a need for quality and standardisation among both state and private forensic service providers. Consideration for forensic science quality, according to the ISO 17025 standards, comprises issues of management requirements and technical requirements which ensure organisational, practitioners and analytical competencies. These quality standard requirements are termed quality management system (QMS) which determines customers' satisfaction about a service or product. This satisfaction is demonstrated via accreditation assessment of the policies, procedures, and processes that exist in laboratories to control and assure the quality of forensic science service and outcome. Accreditation provides an external inspection of the availability of minimum procedures that exist to prospectively ensure quality, reliability, efficiency, and consistency in forensic science service provision. Even though this is not indicative of the highest quality of forensic science outcomes, it ensures that systems are available to mitigate risks of quality failings and non-conformities. Without standards, the competence of forensic personnel and the reliability of equipment and results cannot be assessed [40–44]. As stated earlier, forensic science practice is still in its nascent stages in Ghana and therefore forensic science QMS is in a developmental state. This is evident in the frequent media reports of missing and contaminated forensic evidence material. For example, there was an instance where the police hospital crime lab issued conflicting DNA reports on a rape case which raised questions about the quality of the results and standards used in the lab [9].

To initiate accreditation for the FSL would require the establishment, implementation and maintenance of QMS appropriate to the scope of forensic science activities undertaken by the lab. The assessment of these systems would also require the availability of accredited organisations that are certified to accredit forensic science labs in Ghana. With regards to the latter, there exist various organisations in Ghana who are mandated by law to regulate various professions and laboratories. Specifically, the Ghana Standards Authority (GSA) is responsible for the development and enforcement of standards for laboratories under the Weights and Measures Act 1975 (NRCD 326) [45]. The GSA undertakes testing, inspection, certification and conformity assessment activities. One of the key departments of the GSA is the drugs, cosmetics and forensic unit which undertakes tests and analysis on products and

<sup>1</sup> Some of the available equipment include a comparison microscope for tool-mark analysis; Gas Chromatography-Mass Spectrometer system (GC-MS), Gas chromatography – Flame Ionization Detector system (GC-FID), High Performance Liquid Chromatograph (HPLC) and Infra-Red (IR) spectrophotometer for chemistry and drugs analysis; 7500 Real-Time PCR, 9700 GeneAmp thermal Cyclers, and 3500 Capillary Electrophoresis for DNA analyses; and Video Spectral Comparator (VSC), and Electrostatic Detection Apparatus (ESDA) for documents examination.

samples for the purposes of quality, investigation and medical diagnoses. The specific areas of analysis for the GSA forensic laboratory include drugs of abuse, toxicology and handling of evidential materials [42]. To enhance the quality of forensic services in Ghana, the GSA, in consultation with relevant stakeholders, should adopt the appropriate ISO standards (ISO 17025:2017 [46] for lab analysis and 17020:2012 [47] for crime scene examinations) for the accreditation of forensic science providers. The accreditation assessment should be facilitated by the availability of competent assessors as well as competent personnel within laboratories and adequate funding to pay assessment visits.

With regards to enforcing accreditation requirements for forensic science practice, jurisdictional differences exist but have been primarily via voluntary accreditation requirements. Both mandatory and voluntary requirements may be feasible depending on the availability of statutory instruments for enforcement and behaviour of forensic science providers, including adequate funding and resources. In some instances, even though voluntary accreditation may be widely applied, mandatory accreditation would be required for some aspects of forensic science practice, such as for biometric-related activities [48]. To recommend a model of accreditation for forensic science practice in Ghana, consideration must be given to a cost-effective regime that ensures flexibility and innovation in forensic science practice, encourages the maintenance of quality culture, and promotes best practice.

In South Africa, the South African Council for Natural Scientific Professions (SACNASP) is the body mandated by law to regulate the forensic science service profession while the South African National Accreditation System (SANAS) inspects and certifies all laboratories [44]. In Ghana, there are various statutory bodies to regulate specific professions and accreditation processes. A typical example is the health sector where the Allied Health Professions Council (AHPC), Medical and Dental Council (MDC), Pharmacy Council and the Nurses and Midwifery Council (NMC) are mandated by law to regulate relevant health professions in the country. In 2017, the GSA adopted ISO 15189:2012 as the standard for all medical laboratories in Ghana [49]. Several hospital laboratories have since been assessed and accredited based on ISO 15189:2012 requirements. A similar model like the health sector could be adopted for the accreditation of forensic science providers in Ghana through the proposed Ghana National Accreditation Services (GNAS) [50]. In fact, accreditation system for forensic science providers modelled after that of clinical laboratories, such as the Clinical Laboratory Improvement Amendments of 1988 (CLIA) of the US has been suggested by experts [51].

To regulate the forensic science profession, a statutory body like the health sector councils should be established. The benefit of such a body is the prevention of quackery and unreliable forensic investigation which can affect the fair administration of justice. This body should continuously assess the competence of practitioners and provide certifications which can inform the Court about the competence of forensic science experts. There is presently an informal Forensic Science Society of Ghana (FSSGH) which is hosted at the Forensic Department of the University of Cape Coast. The FSSGH is made up of scientists trained in Ghana, the UK, Australia and Europe. The Society, in consultation with relevant stakeholders, may be backed by statute to support the accreditation of forensic science practices and certification of practitioners in Ghana.

## 6. Impact of forensic science on the criminal justice system

The primary aim of forensic science is to assist law enforcement agencies and the legal system in fulfilling their primary functions such as the prevention, detection, and investigation of crime, and the delivery of justice. The outcome of legal cases in Ghana is

underreported, particularly cases from the lower courts [52]. This challenge makes it difficult to ascertain the contribution of forensic science in legal inquiries. The main sources of information about criminal and other legal cases are through the media. A major area of police inquiry and prosecutions, where forensic science plays a routine role is illegal drug possession and use. In most of these cases, forensic science (drug testing) is used for corroboration purposes to confirm whether an alleged substance is an illegal drug or not. One such example is the case of Iddrisu Yobi [53] described in Box 1. As can be seen in the case, the accused acknowledged possession of the alleged substance prior to forensic testing and this is common in most drug offences. Forensic drug testing is essential because it allows the court to accurately assess the weight of the evidence and inform any verdict and sentence given by the trier of fact or jury.

Another example of a case that involved forensic science is the exoneration of Eric Asante in 2017 (Box 2). In contrast to the above, this case study illustrates how forensic science can be used to resolve or correct miscarriages of justice. It also shows the potential dangers of eye witness account. Further, the case study supports the importance of ensuring that the overriding duty of a forensic scientist is to justice rather than working for either prosecution or defence. This reinforces the argument about adopting a forensic science governance framework that is transparent and independent and protected from organisational biases.

In summary, the two case studies above show the dual effects of forensic applications in convicting and exonerating individuals in the criminal justice system. There is also a wide range of opportunities for the application of forensic science in humanitarian cases. For example, on 3 June 2015, more than 150 individuals lost their lives in the “twin” fire and flood disaster [54]. Some of the challenges encountered in this case included poor scene

### Box 1

#### Case Study on the use of forensic drug analysis

##### Iddrisu Yobi

On 18 May 2017, two law enforcement officers (a police officer and a Bureau of National Investigation (BNI) officer) at Asankragwa in the Western Region of Ghana found a group of young men smoking a substance that was suspected to be cannabis. The officers were able to arrest one member of the group, Iddrisu Yobi, while the other suspects fled. The officers recovered money, 104 wrappers of suspected cannabis in a bag and other items from Yobi. At the police station, Yobi declared in a statement that the items (exhibits) belonged to him. The statement was made in the presence of an independent witness. Yobi was accused of illegal drug possession in an arraignment hearing before the Tarkwa Circuit Court and remanded pending forensic testing of the substance by the FSL of the Ghana Police Service. On 27 August 2017, the report of scientists at the FSL confirmed the seized substance (the 104 wrappers) to be cannabis, including 144.87g of dried leaves and 757.72g of seeds. Yobi was subsequently charged with the offence which he pleaded guilty and was sentenced by the Circuit Court to 10 years in prison custody.

Source: Addo, A. E. (2018, May 26). Drug dealer jailed 10 years in Tarkwa. Retrieved June 17, 2019, from <http://www.ghananewsagency.org/human-interest/drug-dealer-jailed-10-years-in-tarkwa-133206>.

**Box 2**

## Case Study on the use of forensic DNA analysis

**Eric Asante**

In early November 2003, a 14-year old junior high school girl was found by her uncle-in-law writing a love letter to one Mr Eric. The content of the letter indicated she had met Mr Eric the previous day and “given him what he wanted”. She thanked Mr Eric for giving her money and expressed her love for him. She further explained that she was unwell and thus will not be able to visit him. The uncle-in-law alerted the mother and auntie of the girl who questioned her about the letter. She disclosed that Mr Eric is her teacher and boyfriend. The case occurred at Nyohini in the Northern Region of Ghana. The family confronted Mr Eric Asante and he denied the affair. A report of defilement was subsequently made to the Women and Juvenile Unit (WAJU) of the Tamale Police on 14th November 2003. The victim was issued a medical form to attend a medical examination at the Tamale Teaching Hospital where she disclosed to the medical officer that Mr Eric is her boyfriend. She also mentioned that the last time she had sex with Mr Eric was on 12 November 2003. A pregnancy examination of the victim returned positive, showing that she was 23 weeks pregnant. She stated that Mr Eric was responsible for the pregnancy. Although Mr Eric maintained his innocence, he was convicted and handed a 15-year prison sentence for defilement on 5 September 2005 at the Tamale High Court. The Court of Appeal upheld the conviction in April 2006. A further appeal was made to the Supreme Court and an order was issued to conduct a DNA test of the child in 2014. The test was carried out by the Forensic Science Laboratory in July 2015. The appellant was released from prison in September 2015 for good conduct.

The report of the DNA test was adduced as new evidence in the appeal case in July 2016. The DNA result excluded Mr Eric Asante as the father of the child and the initial conviction was quashed in January 2017. However, the Court stated that the “appellant is not entitled to an acquittal on the sole ground that the DNA evidence excludes him”. Nevertheless, in their “judgment, the DNA evidence does tremendous damage to the credibility of the victim and her disposition to speak the truth, in this case, is put in serious doubt”.

Source: *Asante v Republic* [2017] GHASC J3/7/2013.

(Available from <https://ghalii.org/gh/judgment/supreme-court/2017/3>)

management and inadequate forensic science support. As a result, burnt bodies were crammed into vehicles and deposited at various morgues. Further, there were no or inadequate processes (such as DNA identity testing) to identify the bodies and missing persons. Lastly, there was a poor forensic investigation into the cause of the fire and flood due to lack of expertise [55]. The benefits of forensics and the wide range of opportunities for its application emphasise a need for government and stakeholder investment in advancing forensic science in Ghana. This includes capacity building in areas of infrastructure, evaluation of impact, training, research and education.

**7. Forensic science education**

Forensic science degree programmes have become ubiquitous in global higher education systems [56,57]. For example, there are at least 150 institutions/centres in the USA [58], 36 accredited institutions across the United Kingdom [59] and 17 universities in Australia [56]. In Ghana, very few institutions have recognised forensic science programmes. The University of Cape Coast (UCC) received accreditation to run a B.Sc. Forensic Science degree in 2013 but only began enrolment in the 2015/2016 academic year [60]. It is the only institution that runs such undergraduate programme in the country as well as in the West African sub-region, in a dedicated Department of Forensic Sciences (DFS). At the postgraduate level, the Kwame Nkrumah University of Science and Technology (KNUST) offers three specific forensic programmes: MPhil/MSc Forensic Science, MPhil/PhD Human Anatomy and Forensic Science, and MPhil/MSc Cyber-Security and Digital Forensics [61]. The introduction of these postgraduate programmes begun in 2014. One crucial gap in these developments is the limited availability of qualified/trained forensic science academics and researchers. This may be addressed through collaborations with advanced forensic institutions in other countries. The collaborative model is currently a core part of the UCC programme. This will not only ensure that graduates are adequately prepared to meet the challenges of forensic science practice but also enhance the quality of forensic services to the legal system and law enforcement.

*7.1. Accreditation of educational programmes/courses*

The forensic science programmes at UCC and KNUST have been accredited by the National Accreditation Board (NAB) of Ghana [62]. Accredited tertiary institutions in Ghana are required, by law, to submit their academic and professional programmes to the NAB for accreditation before enrolling students. A typical programme accreditation process in Ghana, as spelt out in the NAB's Roadmap to Accreditation [63], consists of completing and submitting extensive paperwork, an inspection of facilities, resources, logistic implication and staff needs of the institution, and a review of assessment reports by an Accreditation Committee (AC). The NAB, based on the recommendations of the AC, decides the outcome of the accreditation process. If required, the institution has within 30 days to challenge the decision, and the NAB is stipulated to conduct a review and communicate a final decision within 90 days of receipt of such application. As specified in the Legislative Instrument LI 1984 [64], an institution can appeal to the Minister responsible for Education, where necessary, within 30 days of receipt of the NAB's review decision.

The NAB accreditation process is not only centralised but unnecessarily cumbersome and requires an urgent review. Per their roadmap, a hitch-free application takes at least 162 working days to arrive at a decision and at least 282 working days if an unfavourable decision is challenged. These timelines are, however, only for guidance since actual turnaround times are stringently tied to how long it takes to assemble the relevant elements of the process. Decentralisation of operations through the establishment of regional NAB secretariats with decision-making powers should reduce accreditation time span. Further, elimination of the manual-based application forms for an online one, the progress of which is trackable via an applicant login upon submission of a full application (and paying the required fee), would be efficient as well as ensure effective documentation and institutional memory. Institutions will be able to respond to any queries promptly online and would not have to travel to the NAB headquarters in Accra - as is currently the case - to follow up and or resubmit corrections. Finally, the establishment of web-based platforms with audio-



visual online meeting functionality should eliminate the need for assessment panels to be physically present at meetings, given its voluntary nature. This will also ensure that personnel with field-specific expertise (home or abroad) are drafted instead of those with ‘general knowledge’ or from ‘closely related area’ as was the case during the accreditation of UCC Forensics.

In the United States, there are agencies accredited by the Department of Education with either regional or national scope of providing accreditation to degree-granting institutions [65,66]. While the United Kingdom does not operate an accreditation system as done in the US, it has the Quality Assurance Agency for Higher Education (QAA) [67,68] which is authorised to safeguard standards and quality in UK higher education. The foregoing bodies are parallel to Ghana’s NAB. However, the importance of forensic evidence in the civil/criminal proceedings means that organisations with highly skilled personnel with expertise in academia and practice in the diverse fields of forensic science have become essential to the national and international recognition of forensic science programmes. For instance, the US Forensic Science Education Programs Accreditation Commission (FEPAC) [69] and the UK Chartered Society of Forensic Sciences [70] provide professional accreditation to institutions to run high-quality undergraduate and postgraduate programmes. Accreditation from such bodies is very relevant because they see the programme suitability, core content, practical and/or training components from a multi-faceted perspective instead of just through a purely academic lens. This degree accreditation model will ensure:

1. The integration of “current global best practices”; and
2. The feasibility of the proposed training given the indicated resources rather than “enticing course content”.

In this respect, the FSSG, in collaboration with NAB and other international bodies, could be instrumental in the development, evaluation, monitoring and enforcement of forensic education standards. This collaborative initiative will ensure that forensic education policies and accreditation are robust, safeguarding high-quality education and training of forensic scientists in Ghana.

### 7.2. Infrastructural capacity

The Forensic science programmes at KNUST primarily rely on the already well-established teaching and research facilities in departments at sciences, medicine and computer science faculties. The institution has, however, strived to acquire discipline-specific facilities to enhance content delivery and training. KNUST has partnered the E-Crime Bureau, a Cyber Security Company, to establish a Digital Forensics Laboratory [71]. The UCC Forensics, similarly, tap from the facilities available at the schools in the College of Agriculture and Natural Sciences [72]. The DFS has recently inaugurated a purpose-built Forensic Sciences Laboratory with four sections: Analytical Sciences & Toxicology; DNA Analysis; Fingerprint & Questioned Documents; and Ballistics/Firearms, each of which houses modern equipment and supplies to meet student training and research needs.

Moreover, the DFS won the 2018 Instrumental Access grant from the Seeding Labs [73] and subsequently received different equipment and reagents [74] to enhance students’ training. To internationalise its forensic science education and imprint world-acclaimed practitioners, DFS has working agreements with the Gujarat Forensic Sciences University, India [75], the University of Lincoln, UK [76] and the University of Cordoba, Spain which allows students to go for internships and, most significantly, learn to use equipment and techniques which are presently not available at the UCC. Where necessary, both UCC and KNUST are given supervised

access to the facility and resources at the GPS FSL for some training. The above progress notwithstanding, more investment in tailor-made infrastructure and equipment, is required to raise training and research to standards with world acclaim.

### 7.3. Employability of graduates (The case of DFS UCC)

The key focus of every degree programme should not be limited to the competence and expertise of the graduates it churns out, but most importantly, the alignment of student outcomes with the future work environment. Thus, the job market-readiness of its graduates, vis-à-vis availability of jobs. The NAB, therefore, requires institutions to provide an unambiguous statement of employability of potential graduates as part of the accreditation process. UCC Forensics has subsequently liaised with institutions within Ghana to highlight the need for forensic science education and the impact that graduates could bring to bear in the performance of their core functions. This has been done through a National Symposium that brought together all industry players, including government and security agencies, where the employment of graduates was strongly justified and advocated [77]. Furthermore, close engagements of DFS with the GPS [78,79], Ghana Military Police and Ghana National Fire Service (GNFS) [80] where current students have undertaken internships; Ghana Immigration Services and some private security firms, should ensure high prospects of graduate employment. Notably, the exclusive collaboration with GPS culminated into DFS winning the Sustainable Development Fund (SDF) to develop training programmes beneficial to security agencies and, ultimately, DFS students [81]. By cooperating with national and international partners, graduates will be able to work in several jurisdictions, especially in the sub-Saharan Africa region where there is a massive human resource gap.

## 8. Forensic science research and development

Research across forensic science practice has generally improved understanding of the significance of forensic science within the legal system. This spans across forensic technologies and innovations, the validity and reliability of forensic science, interpretation of forensic evidence, forensic science management and education, and forensic science law and ethics. These research areas may be tailored to the specific research needs of a particular jurisdiction. In the UK, for example, a recent report highlighted research gaps for technological developments, foundational research into the scientific basis for some forensic methods, and leadership and oversight functions [82]. Further research to investigate the effectiveness/impact of forensic science, DNA database systems [83], and regulation of forensic science in the UK [84] are highlighted by academics. The demand for such impact research has increased [85], given the fact that forensic science practice in the UK has persisted for a long time. This is essential because it can help improve existing practices and justify continuing support and effective distribution of resources for forensic science.

This paper, by highlighting some policy issues of forensic science in Ghana, concomitantly, identifies some research gaps for forensic science. For instance, for issues of underutilisation of forensic science in criminal investigations, challenges could be exacerbated by lack of research which disseminates the value of forensic science. As a result, basic research which shadows crime levels and patterns, illuminates effect on national security, identifies investigative needs of the police and areas where forensic science could be beneficial, should boost further desirability for forensic science practice within the legal system. Addressing these research gaps should also inform and justify the need for spending on forensic

science in Ghana. Currently, research in Ghana, generally, are stifled by lack of funding. A new educational policy proposes an increase in funding for research in public tertiary institutions in Ghana from 0.3% of GDP to 1% [86]. The limited national research funding may proffer some difficulty in promoting forensic science research. This may be addressed through national and international collaborations among relevant research institutions, law enforcement agencies, forensic science providers and governmental and non-governmental funding agencies. A specific Forensic Science Research Institute (FSRI) could be established to coordinate, oversee and disseminate all forensic research activities and outputs. The FSRI could liaise with relevant agencies such as the FSL and Universities to develop and carry out projects that address gaps in practice. An advantage of this approach is the prevention of duplicated research by different research institutions. Further, the FSRI will serve as a unified source of forensic research information in Ghana. Specific funding grants could be established under the FSRI in collaboration with agencies such as the Research and Grant Institute of Ghana, and the Council for Scientific and Industrial Research to support such research projects.

## 9. Conclusion and recommendations

This review examined the status of the different aspects of forensic science in Ghana. The areas scrutinised included legislation, governance, provision of forensic services, quality management, impact, education and training, and research and development. The main objective of the review was to identify key policy issues and provide relevant recommendations drawn from 'best practice' in countries that are more advanced in forensic science. The review is important because it provides a groundwork to assist policymakers in implementing appropriate policies to improve the application of forensic science in Ghana. As highlighted in the review, the realisation of the ultimate purposes of forensic science (including the safe delivery of justice) is dependent on the quality of its fundamental policies and legislation. The key issues identified in the review and corresponding recommendations are summarised below.

**Legislation:** Policymakers should consider best practice from other countries and implement appropriate legislation to govern the use of DNA, fingerprints and other biometrics. This is relevant because the police have already begun creating forensic information databases.

To prevent miscarriages of justice, it is highly recommended that policymakers and relevant stakeholders codify the admissibility tests for expert opinion evidence by drawing from international best practice.

**Governance:** An independent forensic governance approach through the creation of an independent forensic institution or through the leadership of an independent Regulator or Board is recommended. This can help prevent the potential risk of bias in the current police-led framework of governance, ensure discipline and priority for forensic needs, budgetary allocation and generation of funds.

**Forensic service provision:** Clear guidance on terms of service provision by the FSL to the police and other forensic users should be drafted. Further, a national policy on forensics should include appropriate funding and resourcing arrangements to sustain the forensic market. This may include public-private partnerships and national-regional grant schemes or collaborations to address resource and funding needs.

A decentralised model of service provision should also be developed to ensure the timely deployment of forensic services across the regions of Ghana.

**Quality assurance:** The lack of accreditation and regulatory

bodies to oversee the quality of forensic science provision poses a risk to justice. Thus, a national forensic quality policy should be established that requires the adoption of the ISO 17025 and ISO 17020 for forensic service providers. This should be supported by the GSA, the proposed GNAS, the FSSGH, GPS and other relevant bodies.

**Impact of forensic science:** An evaluative programme should be established under an appropriate governing body to monitor and report on the impact and effectiveness of forensic science in the legal system. This will ensure that key challenges/issues are identified and resolved. Further, such information may enhance public support for the application of science in the legal system.

**Forensic science education:** To develop existing degree programmes into internationally acceptable standards, an accreditation model led by a forensic society (such as the FSSGH) or experts should be adopted.

Also, the curriculum for forensic degree programmes should integrate close partnership and interaction with practitioners, forensic service providers and international higher education institutions.

**Forensic science research:** A national policy on forensic science should include a research framework that coordinates all forensic research activities in the country. A Forensic Science Research Institute (FSRI) may be created for this purpose with a focus on addressing research gaps in industry or practice.

## Conflicts of interest

None.

## References

- [1] S. Bitzer, P. Margot, O. Delémont, Is forensic science worth it? *Policing* 13 (2019) 12–20.
- [2] D.M. Lucas, Global forensic science collaboration: standards and research, *Forensic Sci. Policy Manag.: Int. J.* 2 (2011) 148–152.
- [3] A.O. Amankwaa, Trends in forensic DNA database: transnational exchange of DNA data, *Forensic Sci. Res.* (2019) [cited 2019 Mar 15]; Available from: <https://doi.org/10.1080/20961790.2019.1565651>.
- [4] D.M. Lucas, The forensic sciences: ideally, how might they be delivered? *Forensic Sci. Policy Manag.: Int. J.* 4 (2013) 7–22.
- [5] Ghana Police, Forensic science laboratory [Internet]. [cited 2019 Jun 12]. Available from: <https://police.gov.gh/en/index.php/forensic-science-laboratory-fsl/>.
- [6] A. Amankwaa, History of forensic science in Ghana—overview, *Scientect e-mag.* 1 (2016) A1.
- [7] Daily Guide, Police gets forensic Lab [Internet]. 2011 [cited 2019 Jun 18]. Available from: <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Police-Gets-Forensic-Lab-226024>.
- [8] Ghana News Agency, US experts arrive in Kumasi to investigate fire outbreak. *Ghana Business News*, 2013 [cited 2019 Jul 4]. Available from: <https://www.ghanabusinessnews.com/2013/06/18/us-experts-arrive-in-kumasi-to-investigate-fire-outbreak/>.
- [9] M.A. Baneseh, Police Hospital, Crime Lab Give Conflicting Results in Lebanese Rape Case [Internet], *Graphic Online*, 2018 [cited 2019 Jun 12]. Available from: <https://www.graphic.com.gh/news/general-news/police-hospital-crime-lab-give-conflicting-results-in-lebanese-rape-case.html>.
- [10] Office of the President, President Akufo-Addo Presents 200 Vehicles to the Ghana Police Service [Internet], Ministry of the Interior, 2018 [cited 2019 Jun 18]. Available from: <https://www.mint.gov.gh/president-akufo-addo-presents-200-vehicles-to-the-ghana-police-service/>.
- [11] Ghanaian Chronicle, Cocaine Gone Missing at CID Headquarters [Internet], 2008 [cited 2019 Jul 1]. Available from: <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Cocaine-Gone-Missing-At-CID-Headquarters-138542>.
- [12] R. Booth, WikiLeaks Cables: Ghanaian Police "Helped Drug Smugglers Evade Security [Internet], *The Guardian*, 2010 Dec 14 [cited 2019 Jul 1]; Available from: <https://www.theguardian.com/world/2010/dec/14/us-embassy-cables-ghana-airport-drugs>.
- [13] J. Gunter, Murder in Accra: the Life and Death of Ahmed Hussein-Suale, 2019 Jan 30 [cited 2019 Jun 18]; Available from: <https://www.bbc.com/news/world-africa-47002878>.
- [14] 3news, Canada Issues Kidnapping Alert to its Citizens in Ghana [Internet], 2019 [cited 2019 Jun 18]. Available from: <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Canada-issues-kidnapping-alert-to-its->

- citizens-in-Ghana-752694.
- [15] Parliament of the Republic of Ghana, The Constitution of the Republic of Ghana, 1992.
- [16] Cubagee v Asare and Others, 2018. Available from: <https://ghalii.org/gh/judgment/Supreme%20Court/2018/184/RAPHAEL%20CUBAGEE%20VRS%20MICHAEL%20YEBOAH%20ASARE%20%26%202ORS.pdf>.
- [17] Parliament of the Republic of Ghana. Criminal and Other Offences (Procedure) Act, 1960.
- [18] Parliament of the Republic of Ghana. Evidence Act, 1975.
- [19] M. Stockdale, A. Jackson, Expert Evidence in Criminal Proceedings: Current Challenges and Opportunities, *J. Criminal Law* 80 (2016) 344–363.
- [20] A. Kershaw, Professional standards, public protection and the administration of justice, in: J. Fraser, R. Williams (Eds.), *Handbook of Forensic Science*, Willan Publishing, Cullompton, Devon, 2009, pp. 546–571.
- [21] CPS, Expert Witness [Internet], Crown Prosecution Service, London, 2015 [cited 2019 Jun 15]. Available from: [https://www.cps.gov.uk/sites/default/files/documents/legal\\_guidance/expert\\_evidence\\_first\\_edition\\_2014.pdf](https://www.cps.gov.uk/sites/default/files/documents/legal_guidance/expert_evidence_first_edition_2014.pdf).
- [22] ENFSI, ENFSI Guideline for Evaluative Reporting in Forensic Science [Internet], third ed., European Network of Forensic Science Institutes, 2015 [cited 2018 Dec 17]. Available from: [http://enfsi.eu/wp-content/uploads/2016/09/m1\\_guideline.pdf](http://enfsi.eu/wp-content/uploads/2016/09/m1_guideline.pdf).
- [23] J. Chalmers, *Evidence Essentials*, third ed., Edinburgh University Press, Dundee, 2012.
- [24] B. Robertson, G.A. Vignaux, C.E.H. Berger, *Interpreting Evidence: Evaluating Forensic Science in the Courtroom*, second ed., John Wiley and Sons, Inc, Chichester, West Sussex, 2016.
- [25] INTERPOL, *Global DNA Profiling Survey Results 2016*, INTERPOL, Lyon, France, 2016.
- [26] Parliament of the Republic of Ghana. Data Protection Act, 2012.
- [27] Ghana Police, Criminal Data Service Bureau [Internet]. [cited 2019 Jun 15]. Available from: <https://police.gov.gh/en/index.php/criminal-data-service-bureau-cdsb/>.
- [28] Committee on Identifying the Needs of the Forensic Sciences Community, National Research Council, *Strengthening forensic science in the United States: a path forward*, National Academies Press, Washington, D.C, 2009.
- [29] G. Whitman, R. Koppl, Rational bias in forensic science, *Law Probab. Risk* 9 (2010) 69–90.
- [30] Scottish Police Authority, *Forensic 2026 Strategy: Scientific Excellence for Safer Communities* [Internet], Scottish Police Authority, Glasgow, Scotland, 2018 [cited 2019 Jun 17]. Available from: <http://www.spa.police.uk/assets/126884/441011/441165/457127/item7.1i>.
- [31] J. Fraser, A. Ludwig, *Forensic science and policing in Scotland*, in: D. Donnelly, K. Scott (Eds.), *Policing Scotland*, second ed., Routledge, Abingdon, 2011, pp. 375–398.
- [32] G. Tully, *Forensic science and forensic pathology: quality standards and risks*, *Med. Leg. J.* 85 (2017) 117–129.
- [33] G. Tully, *Forensic science in England & Wales, a commentary*, *Forensic Sci. Int.* 290 (2018) e29–e31.
- [34] F.D. Boateng, I.N. Darko, Our past: the effect of colonialism on policing in Ghana, *Int. J. Police Sci. Manag.* 18 (2016) 13–20.
- [35] MyNewsGh, *Police, Presidency, Parliament, GES Most Corrupt Institutions in Ghana - UG Survey* [Internet], MyNewsGh, 2019 [cited 2019 Jul 1]. Available from: <https://mynewsgh.com/police-presidency-parliament-ges-most-corrupt-institutions-in-ghana-ug-survey/>.
- [36] E-crime Bureau [Internet]. [cited 2019 Jul 6]. Available from: <https://e-crimebureau.com/>.
- [37] NIJ, *Forensic Sciences* [Internet], National Institute of Justice, 2019 [cited 2019 Jun 18]. Available from: <https://www.nij.gov:443/topics/forensics/Pages/welcome.aspx>.
- [38] Z. Erzinclioglu, *British forensic science in the dock*, *Nature* 392 (1998) 859.
- [39] EMSOU-FS, *Collaboration Agreement Summary* [Internet], East Midlands Special Operations Unit- Forensic Services Unit, Ripley, Derbyshire, 2015 [cited 2019 Jun 18]. Available from: <https://www.leics.pcc.police.uk/DOCUMENT-LIBRARY/Planning-and-Money/Collaboration/Regional/EMSOU-Forensic-Services.pdf>.
- [40] W.S. Becker, W.M. Dale, Jr EJP, *Forensic science in transition: critical leadership challenges*, *Forensic Sci. Policy Manag.: Int. J.* 1 (2010) 214–223.
- [41] M.M. Houck, Risk, reward, and redemption: root cause analysis in forensic organizations, *Forensic Sci. Policy Manag.: Int. J.* 7 (2016) 106–112.
- [42] G.S.A. Drugs, *Cosmetics and forensic – Ghana standards authority* [Internet]. Ghana Standards Authority. [cited 2019 Jul 2]. Available from: <https://www.gsa.gov.gh/drugs-cosmetics-and-forensic/>.
- [43] A.M. Christensen, C.M. Crowder, *Evidentiary standards for forensic anthropology\**, *J. Forensic Sci.* 54 (2009) 1211–1216.
- [44] A. Olckers, R. Blumenthal, A. Greyling, *Forensic science in South Africa: status of the profession*, *Forensic Sci. Int.: Genet. Suppl.Ser.* 4 (2013) e146–e147.
- [45] Parliament of the Republic of Ghana. Weights and Measures Act, 1975.
- [46] ISO, *ISO/IEC 17025, General Requirements for the Competence of Testing and Calibration Laboratories*, ISO, Geneva, 2017.
- [47] ISO, *ISO/IEC 17020, Conformity Assessment — Requirements for the Operation of Various Types of Bodies Performing Inspection*, 2012 [Internet]. [cited 2019 Jul 6]. Available from: <https://www.iso.org/obp/ui/#iso:std:iso-iec:17020:ed-2:v1:en>.
- [48] Council of the European Union, *Council framework Decision 2009/905/JHA of 30 November 2009 on Accreditation of forensic service providers carrying out laboratory activities*, *Off. J.Eur. Union* 322 (2009) 14–16.
- [49] I. Yire, T. Abbey, *GSA Launches Quality and Competence Manuals for Medical Laboratories* [Internet], 2017 [cited 2019 Jul 6]. Available from: <http://www.ghananewsagency.org/health/gsa-launches-quality-and-competence-manuals-for-medical-laboratories-122875>.
- [50] K. Adams, *Government to Establish Ghana National Accreditation Service* [Internet], Ghana News Agency, 2019 [cited 2019 Jul 2]. Available from: <http://www.ghananewsagency.org/science/government-to-establish-ghana-national-accreditation-service-145955>.
- [51] D. Christian, *How the clinical laboratory improvement Amendments (CLIA) can improve forensic laboratory quality*, *Forensic science policy & management, Int. J.* 2 (2011) 18–27.
- [52] V. Essien, *UPDATE: Researching Ghanaian Law* [Internet], 2016 [cited 2019 Jun 18]. Available from: <https://www.nyulawglobal.org/globalex/Ghana1.html>.
- [53] A.E. Addo, *Drug Dealer Jailed 10 Years in Tarkwa* [Internet], 2018 [cited 2019 Jun 17]. Available from: <http://www.ghananewsagency.org/human-interest/drug-dealer-jailed-10-years-in-tarkwa-133206>.
- [54] N. Gadugah, *Death Toll in Twin Fire, Flood Disaster Hits 200* [Internet], MyJoyOnline, 2015 [cited 2019 Jul 2]. Available from: <http://www.myjoyonline.com/news/2015/June-4th/death-toll-in-twin-fire-flood-disaster-hits-200.php>.
- [55] N. Gadugah, *June 3 Disaster Caused by Cigarette Smoker- Committee - MyJoyOnline.Com* [Internet], MyJoyOnline, 2015 [cited 2019 Jul 2]. Available from: <https://www.myjoyonline.com/news/2015/august-7th/june-3-disaster-caused-by-cigarette-smoker-committee.php>.
- [56] H. Kobus, M. Liddy, *University forensic science Programs: a student attraction strategy or a value-adding partnership with industry?* *Forensic Sci. Policy Manag.: Int. J.* 1 (2009) 125–129.
- [57] A. Samarji, *Forensic science education: inquiry into current tertiary forensic science courses*, *Forensic Sci. Policy Manag.: Int. J.* 3 (2012) 24–36.
- [58] American Academy of Forensic Sciences, *College & university listings* [Internet]. [cited 2019 Jul 6]. Available from: <https://www.aafs.org/home-page/students/college-university-listings/>.
- [59] Chartered Society of Forensic Sciences, *Universities offering educational accredited programmes* [Internet]. [cited 2019 Jul 6]. Available from: <https://www.csofs.org/Universities-Offering-Accredited-Courses>.
- [60] Ghana News Agency, *Cape Coast University to Introduce New Programme* [Internet], 2014 [cited 2019 Jul 6]. Available from: <http://www.ghananewsagency.org/education/cape-coast-university-to-introduce-new-programme-73734>.
- [61] School of Graduate Studies, *Admission of Candidates to Research or Higher Degree Programmes for 2019/2020 Academic Year* [Internet], Kumasi: Kwame Nkrumah University of Science and Technology, 2019 [cited 2019 Jul 6]. Available from: <https://sgs.knust.edu.gh/node/314>.
- [62] National Accreditation Board. *About us* [Internet], National Accreditation Board. [cited 2019 Jul 6]. Available from: <http://nab.gov.gh/about-us>.
- [63] NAB, *Roadmap to Accreditation*, National Accreditation Board, Accra, 2011.
- [64] Parliament of the Republic of Ghana, *Tertiary Institutions (Establishment and Accreditation) Regulations*, 2010. LI 1984.
- [65] Molly, *Understanding Accreditation of U.S. Colleges and Universities* [Internet], Peterson's, 2017 [cited 2019 Jul 6]. Available from: <https://www.petersons.com/blog/understanding-accreditation-of-us-colleges-and-universities/>.
- [66] Department of Education, *Accreditation: universities and higher education* [Internet]. [cited 2019 Jul 6]. Available from: <https://www.ed.gov/accreditation>.
- [67] QAA, *The quality assurance agency for higher education* [Internet]. [cited 2019 Jul 6]. Available from: <https://www.qaa.ac.uk/en/home>.
- [68] P. McGhee, *What Has QAA Ever Done for UK Universities? A Lot, Actually* [Internet], The Guardian, 2014 Oct 20 [cited 2019 Jul 6]; Available from: <https://www.theguardian.com/higher-education-network/blog/2014/oct/20/qaa-uk-university-review-critics>.
- [69] FEPAC, *Forensic Science Education Programs Accreditation Commission: Accreditation Standards* [Internet], American Academy of Forensic Sciences, Colorado Springs, 2019 [cited 2019 Jul 6]. Available from: <http://www.fepac-edu.org/sites/default/files/FEPAC%20Standards%2002172019v1%20.pdf>.
- [70] Chartered Society of Forensic Sciences, *Educational accreditation application process* [Internet]. [cited 2019 Jul 6]. Available from: <https://www.csofs.org/Accreditation>.
- [71] K.B. Donkor, *KNUST gets digital forensics laboratory* [Internet]. Graphic Online. 2017 [cited 2019 Jul 7]. Available from: <https://www.graphic.com.gh/news/general-news/knust-gets-digital-forensics-laboratory.html>.
- [72] CANS, *College of agriculture and natural sciences* [Internet], College of Agriculture and Natural Sciences. [cited 2019 Jul 7]. Available from: <https://cans.ucc.edu.gh/college-of-agriculture-and-natural-sciences-departments>.
- [73] *Seeding Labs, Instrumental Access 2018: University of Cape Coast: Department of Forensic Sciences* [Internet], Seeding Labs, 2018 [cited 2019 Jul 7]. Available from: <https://seedinglabs.org/programs-and-impact/instrumental-access/instrumental-access-2018/ucc/>.
- [74] *Seeding Labs, University of Cape Coast: Instrumental Access Equipment Arrival* [Internet], 2018 [cited 2019 Jul 7]. Available from: <https://www.youtube.com/watch?v=njZXFEkkyMY>.
- [75] L. Mensah, *India's Gujarat Forensic Sciences University Partners UCC to Establish a Forensic Institute* [Internet], University of Cape Coast, 2017 [cited 2019 Jul 7]. Available from: <https://ucc.edu.gh/news/india%E2%80%99s>

- gujarat-forensic-sciences-university-partners-ucc-establish-forensic-institute.
- [76] L. Mensah, UCC and University of Lincoln (UK) Firm up Implementation Strategy for Partnership [Internet], University of Cape Coast, 2017 [cited 2019 Jul 7]. Available from: <https://ucc.edu.gh/news/ucc-and-university-lincoln-uk-firm-implementation-strategy-partnership>.
- [77] L.K. Asamoah, S. Asare, UCC Organises 1st National Forensic Investigation Symposium [Internet], 2017 [cited 2019 Jul 7]. Available from: <http://ghheadlines.com/agency/ghana-news-agency/20171220/66304238/ucc-organises-1st-national-forensic-investigation-symposium>.
- [78] L. Mensah, Delegation from Department of Forensic Sciences Pays Courtesy Call on IGP [Internet], 2017 [cited 2019 Jul 7]. Available from: <https://archive.ucc.edu.gh/news/delegation-department-forensic-sciences-pays-courtesy-call-igp>.
- [79] L. Mensah, UCC Department of Forensic Sciences to Mentor CID Detective Training Academy [Internet], University of Cape Coast, 2018 [cited 2019 Jul 7]. Available from: <https://ucc.edu.gh/news/ucc-department-forensic-sciences-mentor-cid-detective-training-academy>.
- [80] L. Mensah, UCC Department of Forensic Sciences to Train Fire Officers in Forensic Investigations - Atlfmonline [Internet], 2018 [cited 2019 Jul 7]. Available from: <https://www.atlfmonline.com/home/11-campus-news/12229-ucc-department-of-forensic-sciences-to-train-fire-officers-in-forensic-investigations.html>.
- [81] L. Mensah, Department of Forensic Sciences Trains Security Personnel on Crime Scene Management [Internet], University of Cape Coast, 2019 [cited 2019 Jul 7]. Available from: <https://ucc.edu.gh/news/department-forensic-sciences-trains-security-personnel-crime-scene-management>.
- [82] Science and Technology Committee, Forensic Science and the Criminal Justice System: a Blueprint for Change, House of Lords, London, 2019.
- [83] A.O. Amankwaa, C. McCartney, The effectiveness of the UK national DNA database, *Forensic Sci. Int.: Synergy 1* (2019) 45–55.
- [84] C. McCartney, E. Amoako, The UK forensic science regulator: a model for forensic science regulation? *Ga. State Univ. Law Rev.* 34 (2018) 945–981.
- [85] P. Wiles, Annual Report 2018: Commissioner for the Retention and Use of Biometric Material, Office of the Biometrics Commissioner, London, 2019.
- [86] Ghana News Agency, Government to Increase Research Funding for Tertiary Teachers [Internet], 2019 [cited 2019 Jul 2]. Available from: <https://www.ghanaweb.com/GhanaHomePage/NewsArchive/Government-to-increase-research-funding-for-tertiary-teachers-755217>.