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Citation: Evison, Martin (2018) Forensic science policy and the question of governmental University research quality assessment. Forensic Science International, 290. pp. 279-296. ISSN 0379-0738

Published by: Elsevier

URL: <https://doi.org/10.1016/j.forsciint.2018.07.028>  
<<https://doi.org/10.1016/j.forsciint.2018.07.028>>

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**Evison, M.P.** Forensic science policy and the question of governmental University research quality assessment. *Forensic Science International*, in press.

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**TITLE**

Forensic science policy and the question of governmental University research quality assessment

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## **ABSTRACT**

Forensic science policy has been the subject of a series of judicial and parliamentary enquiries in the United Kingdom in recent decades. Forensic science research has been a recurrent theme in their reports, which have included recommendations for research into the economics of forensic service provision; for the development of expertise and centres of excellence; and for research to establish the validity of the forensic sciences. These recommendations reflect similar concerns expressed internationally—particularly in the United States. In the United Kingdom, however, the Forensic Science Service recently enjoyed a near monopoly in research, and limited research funding and activity in the Universities was exacerbated by the lack of visibility of forensic science in government audits of research quality. This study used established methods in evidence-based policy and research quality evaluation to analyse the range, quantity and quality of research submitted to the two most recent audits – RAE 2008 and REF 2014. Strengths and weaknesses in the methods used are discussed, and the findings analysed in relation to wider research policy issues in forensic science. The study concludes that consolidating forensic science as a peer-science in the academy is essential in order to establish a virtuous circle that will sustain research in the discipline—and address wider policy and socio-economic questions that persistently trouble the field.

## **HIGHLIGHTS**

Summary of research outputs submitted in forensic cognate disciplines in RAE2008 and REF2014

Assessment of the value of these exercises in the audit of University research quality in forensic science

Discussion of policy and implications for forensic science research quality assessment

## **KEYWORDS**

Forensic science; research; policy; audit; United Kingdom; RAE 2008; REF 2014

## 1. Introduction

This paper offers an analysis of the current position of forensic science in the specific context of UK government audits of University research quality.

It begins by considering the broader forensic science environment, including the forensic science economy and government policy in forensic science, and moves on to focus on University research quality assessment.

The paper presents an analysis of research outputs submitted to the previous two UK University research quality assessments, the Research Assessment Exercise 2008 (RAE 2008) and the Research Excellence Framework 2014 (REF 2014). In the absence of a specific Unit of Assessment (UOA) for forensic science, indirect methods of quantification are employed, which have the advantage that they offer a comprehensive picture of broadly relevant research submitted to these exercises and the disadvantage that they introduce risks of under- and over-estimation of the quantity of forensic science research submitted.

The methods capture forensic research outputs as they are commonly conceived—that is, in the scientific, mathematical and computational disciplines, along with investigative or court-related complementary behavioural and social research, which extend beyond traditional boundaries.

The methods used follow those applied in other systematic reviews of research and assessments of research quality in transdisciplinary contexts and allow the range, quantity and quality of research outputs submitted to be measured.

The same methods were applied to research outputs in the archaeological, environmental, pathological and craniofacial sciences to provide internal comparative controls.

To assess the approximate representativeness of research outputs submitted to the RAE 2008 and REF 2014 audits as a proportion of wider forensic science research publications, a provisional tally of UK affiliated papers published in four leading international peer-reviewed forensic science journals was also taken.

The results show UK Universities produce a spectrum of auditable quality forensic—as broadly defined—research outputs that are loosely comparable in quantity with those of more traditional and mainstream subjects, incorporating both forensic science research as it is commonly conceived, as well as research offered in other fields of study relevant to investigation and the courts.

Comparison with papers with UK affiliated authors published in four leading forensic science periodicals over the same period typically, but not exclusively, reflected their focus on the forensic sciences as traditionally conceived. These results also showed the major and growing proportion of publications in these journals produced by the Universities relative to other public and private sector forensic science organisations, and the significant contribution that was made by the Forensic Science Service prior to its closure

Direct assessment of the quality profile of forensic outputs is difficult in the absence of a forensic science UOA (Unit of Assessment), as these typically represent a small proportion of the total submissions to a given non-forensic UOA. In REF 2014, however, the facility to return Impact Case Studies does show evidence that forensic outputs—including those from forensic science subjects as they are commonly conceived—are contributing to submissions highly rated for quality.

The results are discussed with reference to proposals for the treatment of forensic science research in REF 2021, and the wider implications for forensic science research policy and strategy.

There are good reasons to be optimistic about forensic science research in UK Universities, but the medium and long-term health of the field requires this research to be more visibly imbedded

in the academic mainstream. In Europe, independent research institutes and University Medico-Legal Institutes offer solutions that combine education and research goals.

In the UK, where research is undertaken predominantly in Universities, somewhat greater and more visible representation in research orientated traditional Institutions would complement that undertaken in admissions orientated former Polytechnics, where research quality is presently under-developed. The absence, however, of a forensic science UOA in these research audits creates a ‘vicious circle’, which introduces a disincentive to Universities to support forensic science research and employ quality research active staff.

The absence of a forensic science UOA also makes the quality ratings assigned to forensic science outputs almost impervious to direct assessment, except in part via Impact Case Studies.

In the UK and other jurisdictions where government audit of University research quality assessment is undertaken, it is strategically vital to ensure that forensic science research has a commensurate presence and visibility relative to the other sciences.

### *1.1. The forensic science economy—funding forensic science provision*

In the UK, forensic science provision devolves to the separate jurisdictions of England and Wales, Scotland and Northern Ireland. In Scotland, laboratory forensic services are the responsibility of the Scottish Police Authority (SPA). In Northern Ireland, they are provided by Forensic Science Northern Ireland (FSNI), which is part of the Ministry of Justice. These structures follow a common model whereby services are provided in government laboratories and by the police, who are responsible for scene of crime work and some forms of technical examination—such as fingerprint comparison. In England and Wales, however, forensic science provision is delivered via a mixed economy of policing organisations with in-house laboratories and private companies.

Contrary to the thriving image conveyed in the media, forensic science is a small and poorly resourced sector of the economy, forming a tiny proportion overall expenditure on policing, prosecution and defence. For illustration, in 2015-16 the aggregate amount paid to the 39 police forces in England given in the Police Grant Report was £7.4 billion (1). The police workforce in England and Wales in 2015 amounted to about 200,000 individuals, including about 127,000 police officers. The Crown Prosecution Service, responsible for criminal prosecutions in England and Wales, reported departmental expenditure of about £490 million in 2015-16, when it employed about 5800 staff (2). In the adversarial criminal justice system of England and Wales, the defence is typically financed via the Criminal Legal Aid scheme delivered by the Legal Aid Agency, sponsored by the Ministry of Justice (MOJ). In the fourth quarter of 2015, the MOJ reported a Criminal Legal Aid workload of 1.3 million cases and an expenditure of £871 million (3)—roughly equating to 5 million cases and £3.5 billion expenditure per annum. These cases include work carried out in police stations and in courts in relation to people accused of or charged with criminal offences, or who are being investigated for a crime, or who are in prison. More serious cases, heard in the Crown Court, amount to about 17 percent of the overall caseload. In 2009, a survey of 1800 firms of solicitors working in Criminal Legal Aid at that time found each firm employed 3.4 individuals on average in Criminal Legal Aid work—amounting to about 6120 employees in total (4)—not including higher court advocates and barristers.

Expenditure on forensic science is notoriously difficult to establish, given the distribution of services between police, government laboratories and private companies. In 2003, a National Audit Office (NAO) report on the Forensic Science Service—then a GovCo laboratory— found that it employed 2700 staff who had analysed 135,000 cases, and achieved an operating income of £128 million—over 90 percent of which came from work for the police (5). Contraction due to falling crime rates and expenditure cuts to policing following the 2008 economic recession, however, meant that by 2012 the loss-making Forensic Science Service, which had entirely ceased to be economically viable,

was closed (6). While some provision moved to the private sector, a substantial proportion was reabsorbed 'in-house' by the police.

The 2014 NAO report found the proportion of the market now serviced by the private sector via a national framework had declined to £60 million per annum, whereas the police internal market had grown from £113 million in 2012-13 to £122 million in 2014-15 (7). Furthermore, police expenditure on third-party services outside of the framework may have amounted to up to an additional £80-90 million. The report noted, however, that data on spending on forensic science was limited, incomplete, inconsistent and difficult to access—especially regarding police expenditure.

Current estimates of the number of employees working in forensic science is similarly difficult to establish—especially in the police sector, but near the time of its closure the Forensic Science Service staff head count had fallen to 1600 employees in total and the largest private laboratory—LGC Forensics—employed 500 (8). In addition to forensic science provided by the police and private laboratories, there is a small, but not insignificant market of individuals and enterprises typically providing services to the defence and funded via Criminal Legal Aid (see above).

Assuming the police service have similar numbers of staff working in forensic science relative to the size of the market, it could be estimated that forensic science in England and Wales employs about 6500 people and is worth about £300 million per annum—including police services, police funded third-party services, framework funded private sector laboratory services, and legal aid funded defence services.

The forensic science economy might be characterised as equivalent to about one percent of that of policing, prosecution and defence in total value, employing about 5 percent of the number of people.

## *1.2. Forensic science policy*

Forensic science thus clearly represents a very small proportion of the criminal justice system. The annual reports of the police and prosecution (1, 2) make no reference to science. In England and Wales—where the total criminal justice workload amounts to over 600,000 cases annually (2), most cases involving forensic science proceed uneventfully.

These observations may go some way to explaining why forensic science appears to be in a recurrent state of crisis in many Western jurisdictions.

Backlogs, procedural failings and flawed forensic science practice underlying miscarriages of justice perpetually feature in the media and academic literature (9, 10). While they represent a very small proportion of cases overall, wrongful convictions are perhaps the most unacceptable of these failings and, given the fundamental role of physical evidence as an arbiter of truth, problems in forensic science are matters of considerable concern amongst policy makers. Ultimately, forensic science scandals undermine public confidence in the justice system—regardless of the overall size of the sector or of the number of cases affected.

When the role of forensic science in miscarriages of justice related to the IRA mainland bombing campaign of the mid-1970s came to light (11), the House of Commons Home Affairs Select Committee (12) criticised the management and funding of the Forensic Science Service and recommended laboratories should be able to charge the police for services. This led to the establishment of the Forensic Science Service as a GovCo and the opening of the forensic market to competition (13).

Substantial government investment into the Forensic Science Service with the advent of forensic DNA profiling did not prevent problems arising, including backlogs and other procedural issues. The House of Commons Science and Technology Select Committee 2002-3 report 'The Scientific

Response to Terrorism' (14) raised criticisms of the scientific culture in the Home Office. Its 2004-5 report, 'Forensic Science on Trial', questioned the transparency of the transition to a GovCo (15). Subsequent reports following the closure of the Forensic Science Service in 2012 have expressed concern that the police had become a customer and competitor in the market (16), that police expenditure was hidden and was threatening market stability (17) and—most damningly—that the government had 'no meaningful strategy' for forensic science (18).

### 1.3. *Forensic science research*

While many classical and historical antecedents are known, the earliest systematic use of forensic science in criminal investigation is widely attributed to the 'Lyon School' of Alexandre Lacassange (1843-1924), Professor of Legal Medicine at the University of Lyon, whose assistant Edmond Locard (1877-1966) formulated the principle 'every contact leaves a trace'. The first systematic approach to human identification was also developed in France, the 'méthode anthropométrique' of Alphonse Bertillon.

Much fundamental work in the forensic sciences has been developed by British scientists, however. Richard Mead FRS (1673-1754) is credited with writing the first book in English on toxicology—'A Mechanical Account of Poisons'—in 1708. John Smeaton FRS (1724-1792) first introduced scientific evidence into court in relation to a civil engineering dispute. The Regius Chair of Forensic Medicine at the University of Glasgow was founded in 1839 by Queen Victoria. Early work on the identification of criminals by dermatoglyphic fingerprinting was undertaken by Henry Faulds (1843-1930), Sir William Herschel (1833-1917) and Sir Francis Galton FRS (1822-1911). DNA profiling for forensic purposes was first described by Sir Alec Jeffreys FRS in 1985.

Despite these major contributions to knowledge, research in forensic science in Britain has progressed in a somewhat piecemeal fashion that has mirrored the faltering trajectory of government policy for forensic science delivery.

The period between 1931 and 1967 saw the establishment of a national forensic science service managed by the Home Office and offered via six regional laboratories and a central research laboratory. A single police laboratory remained—the Metropolitan Police Forensic Science Laboratory in London, which was also ultimately absorbed into the government service. Notwithstanding these organisational arrangements—and the establishment of a dedicated central research laboratory—inadequacies in forensic science research have been a common feature of policy. The Runciman Report (19) produced following the exposure of infamous miscarriages of justice of the 1970s recommended the development of research in the Universities as well as in professional laboratories. Despite this pluralistic recommendation, however, the Forensic Science Service—who had formal responsibility to 'perform advisory functions to Home Office Ministers' (see 5)—affected a monopoly in forensic science research funding in the UK, underpinned by research budgets of *circa* £8 million per annum.

The perhaps predictable consequences of this questionable policy became apparent following the closure of the Forensic Science Service, which eliminated the major single conduit of funded UK forensic science research. In its 2010-12 report, the House of Commons Science and Technology Select Committee highlighted this issue and recommended a national research budget for forensic science (16). The Home Office Chief Scientific Advisor responded with a comprehensive review of research, including that undertaken in the Universities (20). This was not sufficient, however, to satisfy the Science and Technology Select Committee—who in its 2016 report again remarked on the pressing need for more forensics research (17)—or Sir Brian Leveson, whose 'Review of Efficiency in Criminal Proceedings' (20) also recommended more research in the forensic sciences.



Most recently, the annual report of the Government Chief Scientific Advisor 'Forensic Science and Beyond' (21) proposed a wider view of forensic science and argued for much broader applications of relevant methods.

#### *1.4. Forensic science in UK Universities and the Research Excellence Framework exercises*

The contribution of the Universities to research in forensic science in the UK is complex and arose at the earliest stages in the development of the discipline. Briefly, however, four key factors effected its establishment in the Universities. The first was—effectively—a Home Office policy decision to 'divorce' forensic science from legal medicine and establish it in public laboratories, which eventually became the Forensic Science Service (23, 24). This policy represented a divergence from European Universities, many of which continue to house medico-legal institutes active in research, education and practice in forensic science. The second factor, as discussed above, was the Home Office policy decision to invest practically all forensic science research resources into a single entity—the Forensic Science Service.

The third factor relates to the policies of the Universities themselves. On the one hand, several departments of forensic medicine in traditional research Universities have closed in recent decades. For example, the Department of Forensic Pathology at the University of Sheffield (25) was transferred to the Forensic Science Service in 2004 and closed with the demise of that organisation in 2012. On the other hand, a number of—mainly—former Polytechnics or 'post-1992 Universities' have at the same time introduced forensic science degree programmes to rescue admissions to moribund chemistry programmes. These degree programmes have attracted considerable criticism including from the House of Commons Science and Technology Select Committee. The 2004-5 report, 'Forensic Science on Trial' drew attention to the 401 University courses with 'forensic' in the title and the questionable value of offering vocational degrees for which there is no demand. Clive Wolfendale, Deputy Chief Constable of North Wales Police gave evidence that these degrees were 'a savage waste of young people's time and parents' money' (15). Although initiatives to impose standards have been introduced by groups of Universities (26) and the Chartered Society of Forensic Sciences has introduced an accreditation scheme (27), the issue of employability continues to arise as the number of graduates far exceeds the number of job opportunities (28). Furthermore, forensic science laboratories generally prefer to recruit good basic science graduates from traditional Universities.

The fourth contributing factor is the introduction by government of successive audits of research quality in the Universities. The UK research audits are the largest, most complex and longest standing of these exercises—see Auranen and Nieminen (29), for a recent discussion. The first to be conducted was the Research Assessment Exercise (RAE) of 1986, repeated in 1989, 1992, 1996, 2001 and 2008, and replaced by the Research Excellence Framework (REF) in 2014.

Unfortunately, forensic science and medicine have never featured visibly in these exercises, which are a major strategic driver in University policy, and strongly influence investment in research resources and personnel (29). Lack of funding for forensic science research in Universities exacerbated by the Forensic Science Service quasi-monopoly and the absence of a home in the 'REF' has combined with—or likely eventuated—the closure of forensic departments in traditional Universities.

While the contraction of forensic science provision to the justice system has led to some forensic scientists joining the Universities—and bringing valuable experience with them—these staff tend to be case workers rather than researchers, and from declining disciplines rather than expanding ones. Their contribution to quality research and scholarship is understandably doubtful.

Overall, this situation appears to reflect an unhealthy and paradoxical situation where research active Universities have little forensic science research and undergraduate programmes are offered by 'rent seeking' chemistry teachers and ex-practitioners in admissions-orientated former

Polytechnics whose graduates have little prospect of employment in the discipline. It may be a classic example of where the self-interest of individual actors and agencies described in Public Choice Theory—see Butler (30) for an introduction—may lead in the absence of a more enlightened policy.

The recommendations and expectations for forensic science research spelled out in the series of governmental and judicial reports referred to above have not been fulfilled.

Among these were research to ensure services were cost-effective, adequately funded and staffed, operationally efficient, and organised to match caseloads (12); to encourage the development of expertise and centres of excellence, embracing applied research, in the Universities as well as in public sector and commercial laboratories (19); and to establish the validity of the forensic sciences (21), reflecting similar concerns expressed internationally—particularly in the United States (31, 32). To support this research, further recommendations were made to establish a national research budget for forensic science (16); for greater involvement of forensic scientists in REF research impact assessment and the establishment of forensic science as a strategic priority for the Research Councils (17, 20).

The policy recommendations made for forensic science research—although laudable in their intent—do not recognize the reality that, in the contemporary UK context, the research base cannot grow in the absence of a mainstream academic research culture, the value of whose deliverables can be demonstrated in the REF. Without it, research active Universities will avoid investing in staff and infrastructure, research active academic staff will avoid pursuing it and Research Councils will not have quality research to fund or quality researchers to peer-review applications for awards. This ‘vicious circle’ will have to be broken for quality forensic science research to develop sustainably.

The study presented below makes this basic assumption, argued above, that forensic science must deliver quality research as assessed with all other disciplines in the on-going audits of University research quality. The same could be argued for other jurisdictions, internationally, that are subject to governmental research quality audits.

### *1.5. Aims and approach*

#### *1.5.1 Analysis of the range, quantity and quality of forensic science in RAE 2008 and REF 2014*

The study aims to measure the range, quantity and quality of forensic research submitted to the two most recent UK research audits, RAE 2008 and REF 2014, and to discuss the implications of the findings in the context of the policy issues introduced above.

#### *1.5.2 Approach taken*

Submissions to the two most recent audits of research quality in UK Universities—RAE 2008 and REF 2014—are held online, having been uploaded by the Higher Education Funding Council for England (HEFCE). These submissions were downloaded for analysis using a systematic approach founded on text-based searching and non-random chain sampling that is thorough, transparent and repeatable. It uses methods reported in the evidence-based policy literature—e.g. Pullin and Stewart (33)—and in systematic reviews applied to research quality assessment—e.g. Belcher, et al. (34).

Forensic datasets for both RAE 2008 and REF 2014 were collated to permit a comparison of the range and quantity of submissions to each, revealing underlying patterns and trends, and allowing an assessment of University forensic science research quality. A further comparison with papers collated from four leading forensic science periodicals over the RAE and REF periods allowed the representativeness of the audited outputs to be assessed against a more general publication dataset.

The results are discussed in relation to the strengths and weakness of the methods used, and their implications for forensic science education and research policy.

## **2. Data and Methods**

### *2.1. Data sources*

This analysis uses the data for both the RAE 2008 and REF 2014 exercises, which are publicly available online (35, 36). The data records submissions made to HEFCE by 160 Higher Education Institutions (HEIs) to RAE 2008 and 154 to REF 2014, as well as the research quality profiles assigned to them as a result. In both exercises, Institutions made submissions to preferred Units of Assessment (UOAs) classified by academic discipline, including both single and cross-disciplinary permutations. Multiple submissions by individual Institutions to single UOAs were permitted under restricted circumstances by application only. Similarly, several joint submissions were made collaboratively between Institutions and assessed as a unified entity. Within these UOAs, evaluations were conducted by experts drawn from academia and the wider research and professional community, following agreed criteria and working methods overseen by supervisory Main Panels. In RAE 2008, there were 67 UOAs under 15 Main Panels, reduced to 36 UOAs under four Main Panels in REF 2014.

Introductions to both RAE 2008 and REF 2014 submissions can also be accessed online (37, 38). In RAE 2008, each Institution's submission to a UOA was evaluated according to three components: research outputs, research environment and indicators of esteem. Research outputs consisted of publications and other formal deliverables, whereas research environment and indicators of esteem were offered for assessment in the form of formal supporting statements. In the REF 2014 exercise, research outputs and the research environment components were retained and a new third component was introduced, that of research impact. Research impact submissions were made in the form of Impact Case Studies: formal statements evidencing socio-economic benefit arising from research of at least international quality.

In both exercises, there was an option for a submission to a UOA to be associated with a named Research Group.

Each Institution's submission to a UOA was assessed for 'originality, significance and rigour' and assigned an overall quality profile according to the respective criteria for RAE 2008 (39) and REF 2014 (40), as follows:

4*	Quality that is world-leading in terms of originality, significance and rigour.
3*	Quality that is internationally excellent in terms of originality, significance and rigour but which nonetheless falls short of the highest standards of excellence.
2*	Quality that is recognised internationally in terms of originality, significance and rigour.
1*	Quality that is recognised nationally in terms of originality, significance and rigour.
Unclassified	Quality that falls below the standard of nationally recognised work. Or work which does not meet the published definition of research for the purposes of this assessment.

In RAE 2008, individual submissions to a UOA were awarded an overall quality profile. In the REF 2014 exercise, research outputs, environment and impact were awarded individual quality profiles—in addition to the overall assignment.

This analysis is primarily interested in the range, quantity and quality of forensic science in RAE 2008 and REF 2014. Information specifying procedures for the assessment of quality in all disciplines is available online, contained in the panel criteria, UOA descriptions and working methods for each of the 15 Main Panels in RAE 2008 (41) and 4 in REF 2014 (42).

A text-based search of the Main Panel specifications using the term ‘forensic’ confirmed an *a priori* understanding that no UOA in forensic science was offered in either exercise. Some partial accommodation of forensic science was substantiated, however.

In RAE 2008, the UOA descriptor for UOA 44 Psychology incorporated research in forensic psychology as a branch of applied psychology and the boundaries discussed noted the sub-panel would seek advice, as appropriate, from specialist advisers in this and other areas. The UOA descriptor for UOA 58 Linguistics also included research in forensic linguistics.

In the REF 2014 exercise, the UOA descriptor for UOA 17 Geography, Environmental Studies and Archaeology included research in forensic archaeology and that of UOA 24 Anthropology and Developmental Studies included forensic applications in biological anthropology. The references to forensic psychology and forensic linguistics in RAE 2008 were not retained in REF 2014, however.

In REF 2014, the additional facility to submit Impact Case Studies for assessment offered some acknowledgement of the socioeconomic benefit of forensic science. The assessment criteria for ‘Impacts on practitioners and services’ supported acceptance of evidence that ‘forensic methods have been influenced by research’ under Main Panel A and that ‘Expert and legal work or forensic methods have been informed by research’ under Main Panel B. Main panel A incorporates Clinical Medicine; Public Health, Health Services and Primary Care; Allied Health Professions, Dentistry, Nursing and Pharmacy; Psychology, Psychiatry and Neuroscience; Biological Sciences, and Agriculture, Veterinary and Food Science. Main panel B includes Earth Systems and Environmental Sciences; Chemistry; Physics; Mathematical Sciences; Computer Science and Informatics; Aeronautical, Mechanical, Chemical and Manufacturing Engineering; Electrical and Electronic Engineering, Metallurgy and Materials; Civil and Construction Engineering, and General Engineering.

Papers in four leading periodicals published during the RAE 2008 and REF 2014 periods were recovered using the online search engine PubMed.

## 2.2. *Methods of analysis*

The rather limited, sporadic and inconsistent accommodation of research in forensic science in both RAE 2008 and REF 2014, and the absence of a UOA particularly, prevent direct evaluation of forensic science quality profiles, as would have been possible for many or all other academic disciplines. A low-level analysis of research outputs was therefore undertaken. These are recorded as part of the submission data and research quality profiles recorded by HEFCE for both exercises and are available online (43, 44).

These records contain, for example, details of the research output submission’s Institution, UOA, multiple or joint submission details, Research Group, output type, article title, publication title, publisher, volume number, issue number, page numbers, ISBN and ISSN codes, and DOI code. They are sufficiently detailed to allow publications and other relevant research deliverables to be individually identified, but contain limited information regarding the contents of any given output—they do not include either the full text or abstract, for example. As noted above, there is no forensic science UOA in either RAE 2008 or REF 2014. Whilst the UOA to which the item was submitted is

recorded, in the absence of one for forensic science, this is not immediately helpful in identifying forensic science outputs, which are likely to be distributed across cognate and multi-disciplinary units. These outputs can only be identified from the information contained the article and publication titles, or as research outputs submitted by forensic Research Groups or—in REF 2014—in support of Impact Case Studies.

In RAE 2008, journal article and book chapter titles were recorded in the worksheet Long Title column, volume titles in the Short Title column and journal names in the Publisher column. In REF 2014, journal article and book chapter titles were recorded in the Title column, and volume and journal names in the Volume Title column. To access research output records relevant to forensic science, the submission data and research quality profiles for RAE 2008 and REF 2014 were downloaded in spreadsheet compatible format and saved in separate Microsoft Excel workbooks.

Submissions to RAE 2008 were downloaded as a compressed ZIP file from which fifteen Comma Separated Value (CSV) files were extracted (see Supplementary Table S1). The CSV file listing all research outputs (RA2.csv) was saved as a worksheet in a new workbook. The CSV files containing the indexed tables of Institutions, joint submissions, multiple submissions, output types, quality profiles, staff head counts (RA0.csv), Research Groups and UOAs were each copied and appended as separate worksheets to this workbook, which was saved as 'RAE2008\_all\_research\_outputs.xlsx'—the RAE 2008 full output submission workbook.

Submissions to REF 2014 were downloaded as a compressed ZIP file from which a single workbook (REF2014Data.xlsx) was extracted containing separate worksheets listing all research outputs as well as indexed tables of Institutions, output types, Research Groups, submission details (joint and multiple submissions), submission quality profiles and UOAs. As staff profile information is not recorded in this workbook, these data were downloaded as a separate PDF file found online (45). Pages containing the tabulated staff head count data were extracted in Adobe Acrobat Pro and converted into Excel workbook format. Extraneous text was removed and the table appended as an eighth worksheet to the downloaded workbook, which was saved as 'REF2014\_all\_research\_outputs.xlsx'—the REF 2014 full output submission workbook.

Three systematic text-based and non-random chain search methods adopted to identify relevant records.

Firstly, the article and publication columns in the research output worksheets in each workbook were searched using the term 'forensic'—the Excel non-case sensitive SEARCH function was used—and the research output records saved. To permit a simple internal comparative control, identical searches were made using the terms 'archaeological', 'archeological', 'archaeology', 'archeology', 'environmental', 'pathological', and 'craniofacial'. The number of research outputs returned in each search was recorded for each term.

Secondly, Research Groups with 'forensic' in the Research Group name were found and the records of outputs submitted by these groups recovered. Forensic Research Groups were identified by a search using the term 'forensic' in the Research Group name column of the worksheets listing the Research Groups submitted to RAE 2008 and REF 2014. The associated Institution, UOA and Research Group index codes were then used to locate records in the research output worksheets of the relevant workbooks using the Excel function VLOOKUP. Not all research outputs submitted by staff assigned to Research Groups were necessarily coded to those Research Groups in the research output records, however. Therefore, if no research outputs could be found against a Research Group code in the relevant worksheet, a search was conducted manually using the online search pages of RAE 2008 (46) or REF 2014 (47) to manually investigate research outputs submitted by the relevant Research Group. For RAE 2008, staff members and their associated research outputs are listed by staff member name. For REF 2014, the staff members are listed by name, but their associated outputs are not, necessitating further manual searching online for possible REF 2014 outputs submitted by individual staff members. All potential outputs identified in this way were confirmed as submitted via a search of the relevant

research output worksheets in their respective workbooks. Those records not already encountered—as they would have been if they contained the word ‘forensic’ in the article or publication title—were saved. Identical comparative searches were made for Research Groups using the terms ‘archaeological’, ‘archeological’, ‘archaeology’, ‘environmental’, ‘pathological’, and ‘craniofacial’ and the number of Research Groups recorded for each term.

Thirdly, the records of relevant research outputs submitted to REF 2014 in association with Impact Case Studies (ICS) were found and any records not previously encountered were similarly saved. The REF 2014 online search page (47) was again used to identify any ICS submitted by an Institution to a UOA that included Research Groups with ‘forensic’ in the Research Group name (irrespective of whether the study involved a Research Group member) and to identify ICS with ‘forensic’ in the title. The formal statements for these ICS were downloaded manually online. Any research outputs referred to in them were noted and a cross-referencing search made of the REF 2014 research output worksheet to establish if they had been included in the research output submission. If any of these ICS were associated with Research Groups not having ‘forensic’ in the Research Group name (these had already been analysed), the Institution’s submission to the relevant UOA was searched manually online to identify any further research outputs. Records of research outputs not already encountered were saved.

A general search of the REF 2014 ICS database (48) was also undertaken using the search term ‘forensic’ in order to capture ICS referring to forensics in the body of the text, but not in the title or research group name.

Collation and quantitation of these records to RAE 2008 and REF 2014 permitted a comparison of the range, quantity and types of outputs submitted to be undertaken and an analysis of patterns in submissions of forensic outputs in the two exercises to be offered.

Subsequent cross-referencing of Institutional submissions in any given UOA to the associated research quality profile and staff head count permitted an assessment the contribution of ‘forensic’ outputs to the overall quality profile of the research output submission and—for REF 2014 only—the contribution of ‘forensic’ ICS to the overall quality profile of the Impact Case Study submission. Information regarding the rules for submissions to REF 2014 can be found online (49).

The value used to describe staff head count was the number of ‘Category A’ staff, defined as “academic staff with a contract of employment of 0.2 FTE or greater and on the payroll of the submitting HEI on the census date (31 October 2013), and whose primary employment function is to undertake either ‘research only’ or ‘teaching and research’”.

Quality outputs were defined as those achieving a 3-4\* ranking in the 0-4\* scale.

Where submissions were affected by Institutional and UOA structural changes between exercises, RAE 2008 submissions were cross-referenced to their REF 2014 equivalents. Equivalent UOAs used in RAE 2008 and REF 2014 are given online (50).

Summary descriptive statistics were calculated for each Institutional submission to a UOA. These additionally included research quality rankings and staff head counts, and were used to provide a provisional assessment of research quality. Overall quantitative results were calculated and tabulated by UOA within Institution for both RAE 2008 and REF 2014, to permit comparison of the range, quantity and quality of submissions to each, revealing underlying patterns and trends.

Finally, text-based searches for UK papers published during the RAE 2008 and REF 2014 assessment period were undertaken using the search terms ‘UK’ and ‘United Kingdom’ in the affiliation option in the online search engine PubMed (51), for the following periodicals: *Forensic Science International*, *Forensic Science International: Genetics*, *Journal of Forensic Sciences* and *Science and Justice*. The results were downloaded to an Excel Workbook for analysis and comparison with

outputs submitted to the two University research audits. Outputs counts were summarised by submitting organisation and discipline.

### **3. Results and Discussion**

#### **3.1. *Quantity of research outputs submitted to RAE 2008 and REF 2014 with ‘forensic’ in the article or publication title, and comparison with other search terms***

Using the above methodological approach, a total of 214,287 research output submissions made to RAE 2008 were downloaded and a total 190,963 made to REF 2014.

Tables 1 and 2 list outputs with the word ‘forensic’ in the article or publication titles submitted to RAE 2008 and REF 2014, respectively. Duplicate records—due, for example, to both the article and journal titles containing the word ‘forensic’—were excluded. The results of comparative single word searches conducted using the same method are shown in their corresponding columns.

Results indicate ‘forensic’ research outputs were submitted in similar, but slightly growing numbers to RAE 2008 and REF 2014, showing a significant rise in proportion, however, from 13 to 21 percent. In contrast, there seems to be a noticeable (*circa* 32 percent) decline in submissions found using similar search terms in archaeology. Environment research output submissions show a minor fall (*circa* 9 percent). There are also falls in the totals of submissions found using the remaining search terms—especially in pathology (*circa* 21 percent). The totals in ‘craniofacial’ are small.

#### **3.2. *Quantity of research outputs submitted to RAE 2008 and REF 2014 associated with Research Groups with ‘forensic’ in the Research Group name***

The results of searches for Research Groups with the word ‘forensic’ in the Research Group name in the submissions to RAE 2008 and REF 2014, respectively, are shown in Table 3. The results of other comparative single word searches in the Research Group name obtained in an identical way are also shown.

The increase in research output submissions in ‘forensic’ is reflected in an increase in the number of Research Groups with ‘forensic’ in the Research Group name. The falls in submissions in archaeology, environment and pathology are also reflected in falls in the numbers of associated Research Groups.

Of 3888 Research Groups making submissions to RAE 2008, six contained the word ‘forensic’ in the Research Group name (see Table 4).

A search of all research output submissions to RAE 2008 by Research Group code yielded 69 outputs from four of these six Research Groups. Of these outputs, six were already saved. For two groups, no outputs could be matched against the Research Group code. A manual online search of these two Institution’s submissions to the relevant UOA established each of these Research Groups were associated with the submissions of single members of staff, each of whom had submitted four research outputs to RAE 2008. Of these eight, four—the output of a single staff member—were again already recovered. The remaining 67 previously undetected outputs were saved, yielding a total of 253 research output submissions.

The output types of these research outputs are listed in Table 5.

Of 3496 Research Groups making submissions to REF 2014, nine contained the word ‘forensic’ in the Research Group name (Table 3). A search of all research output submissions to REF 2014 by Research Group code yielded 43 outputs from four of these nine Research Groups, of which two

outputs were already encountered. For five of the Research Groups, no outputs could be matched against the Research Group code. Manual online investigation of submissions by the relevant Institutions to the UOAs associated with these Research Groups allowed the staff members who submitted in these Research Groups to be identified, along with a further 40 research outputs. Of these, three were already recovered. The remaining 78 previously undetected records were saved, yielding a total of 275 research output submissions.

In RAE 2008, four of the six Research Groups submitted were in forensic psychology or forensic mental health, and submitted to UOAs in Other Hospital Based Clinical Subjects; Psychiatry, Neuroscience and Clinical Psychology, and Psychology. A single Research Group in forensic science was submitted to the UOA in Geography and Environmental Studies and single Research Group in forensic pathology was submitted to the UOA in Other Hospital Based Clinical Subjects.

Similarly, in REF 2014, of nine Research Groups submitted, seven were in forensic psychology and all were submitted to the UOA in Psychology, Psychiatry and Neuroscience. This REF 2014 UOA combined the RAE 2008 units Psychiatry, Neuroscience and Clinical Psychology, and Psychology. A forensic biology Research Group was submitted to Biological Sciences and a Multimedia and Forensics Research Group to Computer Science and Informatics.

### *3.3. Quantity of research outputs in forensic submitted to REF 2014 associated with Impact Case Studies*

#### *3.3.1 Quantity of research outputs submitted to REF 2014 referred to in Impact Case Studies associated with Research Groups with 'forensic' in the Research Group name*

The manual online search for REF 2014 Impact Case Studies submitted by an Institution to a UOA that included Research Groups with 'forensic' in the Research Group name (see Table 6) yielded 10 studies of which nine (Table 7) had direct relevance to the justice system. These ICS were submitted to the UOA in Psychology, Psychiatry and Neuroscience.

From the statements associated with these nine studies, 16 research output submissions were identified, of which five were already recorded, having 'forensic' in the article or publication title. A further six were already recorded in association with previously searched Research Group submissions—three were coded to a Research Group and three associated with a Research Group, but not coded to one (see above). The remaining five research output submissions were recovered, yielding a total of 280.

#### *3.3.2 Quantity of research outputs submitted to REF 2014 referred to in Impact Case Studies with 'forensic' in the Impact Case Study title*

Finally, the manual online search of REF 2014 Impact Case Study submissions with the word 'forensic' in the title yielded 18 studies (Table 8).

These reflected greater diversity, having been submitted to UOAs in Biological Sciences ( $n=3$ ); Earth Systems and Environmental Sciences ( $n=3$ ); Chemistry ( $n=1$ ); Mathematical Sciences ( $n=2$ ); Computer Science and Informatics ( $n=1$ ); Architecture, Built Environment and Planning ( $n=1$ ), Geography, Environmental Studies and Archaeology ( $n=2$ ); Law ( $n=1$ ); Modern Languages and Linguistics ( $n=2$ ); Art and Design: History, Practice and Theory ( $n=1$ ). Only one was submitted to the UOA in Psychology, Psychiatry and Neuroscience.

As noted above, the assessment criteria for impact in Main Panels A and B both include forensic methods, and most of these ICS were submitted to UOAs under these Main Panels.



Interestingly, however, ICS submitted in Geography, Environmental Studies and Archaeology and Modern Languages and Linguistics were submitted to Main Panel C, which did not include impact on forensic methods and so on in its assessment criteria. Research outputs in forensic anthropology and archaeology were specified in the associated sub-panel descriptors, but forensic linguistics—which was specified in the REF 2008 descriptors—did not feature in them in REF 2014. The remaining ICS submitted in Architecture, Built Environment and Planning and in Law under Main Panel C and to Art and Design: History, Practice and Theory under Main Panel D were offered despite the absence of any reference to forensic in either the UOA sub-panel descriptors or criteria for impact.

From the statements associated with these studies, 17 research output submissions were identified, only two of which had already been recorded, having ‘forensic’ in the article or publication title. None had been encountered as outputs linked to submissions associated with Research Groups or their ICS. The remaining 16 research outputs—amounting to about 7 percent of the total—were saved, generating a final total of 296 (see Table 9).

### *3.3.3 Quality and contribution of Impact Case Studies submitted to REF 2014*

The analysis of submissions associated with ICS with ‘forensic’ in the title or Research Group name indicate that submissions in Psychology tend to be most frequent ( $n=10$ ). Submissions ( $n=17$ ) to other UOAs are widely spread across academic disciplines under all Main Panels, including those in which there is no reference to forensic in either sub-panel descriptors or impact criteria.

Quality profiles are assigned separately to Impact Case Study submissions, which are generally much fewer in number than research outputs. Therefore, ICS submitted by ‘forensic’ Research Groups form a much larger component of an overall Impact Case Study submission by an Institution to a UOA.

Table 6 shows the proportion of forensically-relevant (see above analysis of associated research outputs) ICS associated with ‘forensic’ Research Group submissions. These contributions vary between zero and 75 percent. Table 7 shows the 3-4\* rating of the overall Impact Case Study submission within which these contributions form a component. In summary, forensically-relevant ICS (Table 6) made a 40 percent contribution to the University of Birmingham submission, a 25 percent contribution to the University of Liverpool submission, a 67 percent contribution to the University of Central Lancashire submission, a 75 percent contribution to the University of Kent submission and a 50 percent contribution to the University of Portsmouth submission. All these submissions were made in Psychology and all achieved a 100 percent 3-4\* rating overall (Table 7).

Table 8 shows similar information for ICS with ‘forensic’ in the title. Except for the 11 ICS submitted to Biological Sciences by Imperial College London and 10 submitted to Mathematical Sciences by the University of Edinburgh jointly with Heriot-Watt University, single ‘forensic’ ICS form components of overall submissions of five ICS or less.

In these latter cases, ‘forensic’ ICS made a 33 percent contribution to the Aston University submission to Modern Languages and Linguistics, which achieved a 73.3 percent 3-4\* rating, a 20 percent contribution to the Bangor University submission to Earth Systems and Environmental Sciences, achieving 90 percent 3-4\*, a 33 percent contribution to the City University London submission to Mathematical Sciences, achieving 80 percent 3-4\*, a 50 percent contribution to the Keele University submission to Computer Science and Informatics, achieving 40 percent 3-4\*, a 3 percent contribution to the Leeds Beckett University submission to Architecture, Built Environment and Planning, achieving 36.7 percent 3-4\*, a 50 percent contribution to the Liverpool John Moores University submission to Law, achieving 100 percent 3-4\*, a 25 percent contribution to the Queen Mary University of London submission to Geography, Environmental Studies and Archaeology, achieving 80 percent 3-4\*, a 25 percent contribution to the Queen’s University Belfast submission also to Geography, Environmental Studies and Archaeology, achieving 80 percent 3-4\*, a 20 percent

contribution to the University of Bristol submission to Biological Sciences, achieving 88.6 percent 3-4\*, and a 20 percent contribution to the University of Dundee submission also to Biological Sciences, achieving 100 percent 3-4\*. Again, these results confirm the quality of 'forensic' ICS to REF 2014, particularly in Psychology, but also in a further broad range of UOAs.

The distribution by UOA of 141 ICS containing 'forensic' in the text is illustrated in Fig. 1., which includes the 28 ICS referred to above.

### *3.4. Trends in forensic research output submissions to RAE 2008 and REF 2014*

#### *3.4.1 Multiple submissions of forensic research outputs submitted to RAE 2008 and REF 2014*

The RAE 2008 and REF 2014 rules allowed—under certain circumstances—for multiple-authored research outputs to be submitted to more than one UOA or by more than one Institution—for example, if co-authors were affiliated to different Institutions. Of the 253 'forensic' research outputs submitted to RAE 2008, two were submitted by two different Institutions to the same UOA, five were submitted by the same Institution to two different UOAs and seven were submitted by two different Institutions to two different UOAs. Of the 296 'forensic' research outputs submitted to REF 2014, four were submitted by two different Institutions to the same UOA, one was submitted by the same Institution to two different UOAs, six were submitted by two different Institutions to two different UOAs, one was submitted by three different Institutions to three different UOAs, one was submitted by three different Institutions to the same UOA and one was submitted twice by the same Institution to the same UOA (this was a substantial two-author volume).

In only one case did an Institution make two submissions to a single UOA—permissible in exceptional circumstances. Cranfield University made two submissions from separate Research Groups—Materials and Applied Chemistry and Engineering Systems and Simulation General Engineering—to the UOA in Mineral & Mining Engineering.

#### *3.4.2 Overall trends in forensic research outputs submitted to RAE 2008 and REF 2014 by UOA*

Research output submissions in forensic submitted to RAE 2008 and REF 2014 are summarised by UOA in Table 10. The UOA structure changed between exercises. Analysis shows 253 outputs were submitted to 23 of a possible 67 UOAs in RAE 2008 and 296 outputs submitted to 28 of a possible 36 UOAs in REF 2014. Thus, forensic submissions are more widely spread among academic disciplines in REF 2014, even though the number of available groupings was fewer. Submissions appeared in REF 2014 in Agriculture, Veterinary and Food Science; Physics; Architecture, Built Environment and Planning; Music, Drama, Dance and Performing Arts; Communication, Cultural and Media Studies, and Library and Information Management, which had not appeared in the relevant precursor UOAs in RAE 2008.

Units of assessment to which most 'forensic' outputs were submitted include Psychology, Psychiatry and Neuroscience; Computer Science and Informatics; Allied Health Professions, Dentistry, Nursing and Pharmacy, and Social Work and Social Policy. The engineering sub-disciplines and Law were also well represented. Among the basic sciences, forensic research outputs were most frequently submitted to Biological Sciences. Submissions to Chemistry and Physics were few.

The results confirm the continuing research productivity of forensic psychology and the growth in forensic research in computer sciences, which increased seven-fold between RAE 2008 and REF 2014. Research on the socio-legal dimensions of forensic disciplines is also popular. Submissions in the physical sciences are disappointing. This probably reflects 1) the rather disingenuous tendency

of former Polytechnics to use the popularity of forensic science as a draw to attract undergraduate admissions to service failing chemistry courses rather than to advance knowledge in forensic science itself, 2) the marginal contribution of ex-practitioners in former Polytechnics to quality research and 3) the interest of only a few top-tier University Departments research in forensic science, even fewer of which support forensic science education at the undergraduate and postgraduate level.

### *3.4.3 Provisional assessment of research quality ratings of forensic outputs*

In Table 11, summary descriptive statistics are offered to provide a provisional assessment of research quality, and changes between RAE 2008 and REF 2014. Summary descriptive statistics were calculated for each Institutional submission to a UOA. These were percent quality outputs (3-4\* ranked outputs) overall, number of staff members submitted overall, number of 'forensic' outputs submitted, number of 'forensic' outputs submitted per staff member, ratio of number of 'forensic' outputs to percent quality outputs overall, proportion of 'forensic' outputs out of the possible total (calculated as 4 outputs per staff member submitted) and ratio of percent quality outputs to the proportion of 'forensic' outputs out of the possible total. The latter values were used to provide an indication of the contribution of 'forensic' outputs to overall research quality.

Maximum, minimum and average values for each statistic for RAE 2008 and REF 2014, and the percent change between each exercise, were calculated (see Table 11). Changes to both Institutions and UOAs between RAE 2008 and REF 2014 were addressed by assigning classifications from RAE 2008 to their REF 2014 counterparts, and similarly by using the successor Institution current in REF 2014 for Institutions submitting to RAE 2008 that were no longer in existence.

The highest 3-4\* rating incorporating 'forensic' outputs in RAE 2008 was 85 percent, achieved by the University of Manchester in Nursing and Midwifery—however, the submission included only one 'forensic' output out of a potential total of 232—based on the maximum of four possible submissions per submitted member of staff. In REF 2014, the highest 3-4\* rating was 97.5 percent achieved in Chemistry by the University of Bristol. Again, however, the submission included only two 'forensic' outputs out of a possible 234.

The largest number of 'forensic' research outputs submitted to a single UOA in RAE 2008 was 34, submitted by the University of Liverpool to Psychology. The largest number in REF 2014 was 22 outputs, submitted by the University of Portsmouth to Psychology, Psychiatry and Neuroscience. These Institutions also submitted the largest number of outputs in 'forensic' overall in the respective exercises.

These results illustrate the difficulty in assigning research quality and performance values to the 'forensic' research outputs, which typically form only a small component of the overall submission. The influence of 'forensic' outputs was estimated by calculating the ratio of the 3-4\* rating to the number of 'forensic' outputs as a proportion of total possible outputs. As staff were not required to submit the maximum of four outputs, this is only a possible total and the forensic contribution is therefore likely to be an underestimate.

Table 11 shows that the average number of 'forensic' outputs out of a possible maximum of four was 0.160 or 4.0 percent in RAE 2008 and 0.113 or 2.8 percent in REF 2014. In one instance in RAE 2008, however, all four research outputs—submitted by Leeds Trinity & All Saints University to Psychology—were 'forensic' outputs. None achieved a 3 or 4\* rating. Only two other submissions to RAE 2008 included a 'forensic' contribution of greater than one out of four outputs. These were both submissions to Psychology: that of the University of Liverpool at 1.2 out of four, which achieved a 30 percent 3-4\* rating, and that of the University of Portsmouth at 1.4 out of four, achieving 25 percent. Only one submission to REF 2014 included a 'forensic' contribution of greater than one out of four outputs. That was again the University of Portsmouth's submission in Psychology, Psychiatry and

Neuroscience at 1.1 ‘forensic’ outputs out of four, with a substantially improved associated 3-4\* rating of 57.3 percent.

These findings show that except in unusual circumstances, it is not possible to directly associate the research quality of ‘forensic’ research outputs by analysing the values assigned to the overall submissions within which they were included in a meaningful way, as their contribution typically forms too small a component.

Submissions including ‘forensic’ research outputs are offered in greater detail in Supplementary Table S3. For each Institution the number of UOAs submitted to and number of outputs submitted are totalled. The details of relevant UOA submissions within each Institution—where they were made—are listed, including the total number of outputs, total staff and overall research quality (percent 3-4\* ranked outputs) by UOA. It is important to note that these totals are those assigned to the relevant Institution and UOA overall, and not just to the ‘forensic’ research output submissions, which generally form only a small component of the total.

The results show that the percentage of 3-4\* ratings generally improved between exercises, a finding observed overall as reported by HEFCE (52).

This Table further confirms the exceptionally broad spectrum of UK HEIs making submissions containing ‘forensic’ research outputs. These include world leading institutions such as Oxford University, Cambridge University, Imperial College London and University College London, and several research-intensive Russell Group Universities. A full range of other Universities and former Polytechnics are also incorporated.

### *3.5. Comparison with UK outputs submitted to leading forensic science journals*

Numbers and types of outputs published in for leading forensic science periodicals during the RAE 2008 and REF 2014 periods are given in Table 12. It is important to note that the affiliation recorded in online publication databases is typically that of the corresponding author only, and therefore the Table includes only those publications in which UK or United Kingdom appear in the corresponding author’s affiliation. The distribution of these publications by organisation type are given in Fig. 2. Provisional allocations of the University affiliated outputs by discipline are given in Table 13.

### *3.6. Sources of under- and over-estimates of quantity of forensic research outputs submitted to the RAE 2008 and REF 2014 exercises*

There are a several potential sources of error leading to the under- and over-estimate of the quantity of research outputs detected using a text-based search. Clearly, not all forensic research outputs will include the term ‘forensic’ in the article or publication title. Conversely, the term has become a metaphor for methodological rigour and stringency that may have no meaningful connection with the usage concerned with the justice system or courts. Similar qualifications could be made regarding the use of the other text-based search terms: ‘archaeology’, ‘environmental’ and so on. These results must be considered in the light of these caveats.

The search term ‘forensic science’ could have been chosen with the aim of detecting more specific forensic science research in the article or publication titles. This approach would have excluded those phrases in which forensic is used as an adjective, however, which is arguably a more commonly relevant use of the word. Every approach appears to have its own flaws.

In both RAE 2008 and REF 2014, submissions by Research Groups amount to about 26 percent of the overall total. The count of research outputs submitted in association with Research Groups

offers a provisional means of assessing the proportion of relevant outputs submitted in forensic that do not have 'forensic' in the article or publication title. In RAE 2008, 67 outputs (25 percent) associated with Research Groups did not have 'forensic' in the article or publication title (see Table 5). In REF 2014, the number was 99 (33 percent), including 21 outputs associated with ICS that did not have 'forensic' in their article or publication titles.

#### 4. Summary

The results show that submissions made to RAE 2008 and REF 2014 included a substantial number of 'forensic' research outputs, that grew slightly in total between exercises and did so more significantly in overall proportion.

The overall totals (Table 10) are loosely comparable with submissions made in archaeology and environmental sciences, and pathology, but show greater sustainability. Falls in the totals in archaeology may reflect in the recent decline in the popularity of archaeology among undergraduates, as discussed recently in *The Guardian* newspaper (51). Pathology has seen a long decline in popularity as a speciality choice in medicine (52) and as a component of the educational curriculum in medicine (53). The fall in the total submissions in 'environmental' is surprising given the moral panic associated with 'man made global warming'. The decline is relatively small, however.

The range of disciplines submitting 'forensic' research outputs is broad, reflecting the range of academic disciplines that have relevance to forensic investigation and the courts. While submissions are skewed toward non-traditional forensic subjects, such as Psychology—including, for example, research in cognitive bias, a range of traditional scientific disciplines are represented that incorporate forensic science as it is commonly conceived. Forensic submissions increased between exercises in Biological Sciences and Engineering, and did so markedly in Computer Science. Outputs in submissions made to Chemistry and Physics are disappointingly small, however.

Output types consist predominantly of journal articles (Tables 5 and 9), indicating a strong element of specialist peer review of outputs.

REF 2014 ICS (Tables 7 and 8) show a similar broad distribution, and include many that were highly ranked in quality. This is a valuable observation, as it shows evidence of research quality that is difficult to measure directly in Institutional submissions to UOAs, within which forensic science outputs typically form only a small component. It demonstrates quality in impact of research relevant to forensic science as it is commonly conceived. The results also show the broad range of ICS submitted with 'forensic' somewhere in the text (Fig. 1), and the broad popularity of claims of forensically-relevant socio-economic impact amongst University researchers.

Ultimately, the absence of a specific UOA to which forensic science research outputs can be submitted means only indirect and inexact methods such as those used in this study can be applied to the measurement of forensic science's contribution to these research audit exercises. Plans proposed for REF 2021 to invite Institutions to identify—specifically—forensic science outputs during the process of submission, in whichever UOA they are submitted, to permit appropriate assessment were put forward to HEFCE in 2018 (56). While this mechanism is intended to allow more informed assessment of University forensic science research quality, it relies on Universities to identify forensic science research when submitting outputs to other UOAs and is only intended to "generate a quality profile for all forensic science outputs that will be combined in the main panel overview reports with a section on forensic science submissions" (56). Unlike other academic disciplines, forensic science research quality will still not be directly assessed by Institution and UOA in REF 2021. The importance of ICS is planned to grow for REF 2021 (56), however, offering some more opportunity to demonstrate and measure the quality of socio-economic impact of University research relevant to forensic science.

It is important, however, to consider certain broader issues in research quality assessment—what is being measured, how is it being measured and who is measuring it?

The etymological definition of forensic science—science in the service of the courts—readily incorporates the broad range of basic and complementary sciences that returned ‘forensic’ outputs to RAE 2008 and REF 2014. A narrower definition considers forensic science to be the application of the basic or natural sciences to criminal investigation, as well as the analysis and interpretation of patterns or marks in specifically forensic contexts. This is arguably the traditional or commonly understood definition. An even more restrictive definition might focus on the latter questions, meaning that forensic science is the unique science of the events and activities of a crime.

A second issue concerns the argument that audits of University research quality do not provide a useful measure of forensic science research quality. Forensic science—as commonly understood—outputs submitted to the audits map only partially onto the Institutions submitting evidence to the Silverman Review of Research and Development in Forensic Science (20), for instance. This was intended to provide a review of UK Universities—and other organisations—that are doing research in the field. This may reflect an acknowledged risk of underestimation in the method used in this study (see 3.5 above)—or that some Universities making submissions regarding their research in forensic science to the Silverman Review did not submit outputs to RAE 2008 or REF 2014. Outputs submitted to RAE 2008 and REF 2014 comprise only a small proportion of UK-affiliated forensic science research outputs submitted to leading forensic science periodicals, however, and the latter include a substantial proportion of outputs produced by non-University public and private sector organisations, which are reflected in the Silverman Review (20).

There may be a valid argument that research published in specialist peer-reviewed journals is evidence enough of quality or that journals operate to different quality standards—for example, an RAE 2008 or REF 2014 1\*-rated output could be considered an interesting and innovative study worthy of publication in a specialist journal, but in an environment of persistent government audits of University research internationally (29) this is not satisfying. Furthermore, it would raise the question as to why University research publications were not returned, given that the benefits in resources and standing are considerable, including a share of a £1.6 billion research funding “QR” pot (57). It also means making highly questionable unique special pleading for forensic science relative to practically every other substantial field of knowledge.

The general issue of the need for a research culture in forensic science has been raised by academic lawyers—e.g. Mnookin et al. (58) and sociologists (59, 60). The Mnookin et al. paper is co-authored by a heterogeneous group representing forensic science, psychology and law. They state: “Our central argument is that the pattern identification disciplines, and forensic science more generally, do not currently possess—and absolutely must develop—an adequate research culture”.

In response to Mnookin et al., Margot (61) makes the important point that research must “address primarily forensic science questions—not questions relating to the application of chemistry, biology, statistics, or psychology”—forensic science must become a “fully-recognized discipline with its own territory”.

Similarly, Linacre (62) argues for more creative research in Universities, if it is integrated within the wider community, but more explicitly emphasises the need for a balance between high level education and one where this is unnecessary. To some extent, this reflects the reality that in forensic science there is a broad range of intellect and technical competency, much of which is outwith the University sector.

Both Mnookin et al. and Margot appear to acknowledge divides between the pattern identification—orientated disciplines and those forensic sciences embedded within the scientific mainstream, and between University based researchers and practitioners. Margot acknowledges “Most practitioners involved in the analysis of fingermarks, toolmarks, and firearms marks are not

scientists and have little, if any, training in science”, indicating a demand for more scientific research and education in these subdisciplines. Mnookin et al. make the balanced argument:

“if some relatively small fraction of practitioners were full citizens of both the world of research and the world of practice, it would offer enormously beneficial spillover effects. These practitioner-researcher hybrids could wear two hats by being true insiders in both communities. They would be valuable translators, mediators, and educators in both domains. They could both convey to fellow practitioners the need for a research-based approach and contribute to ensuring that research focuses on areas of genuine and important concern to practitioner”.

Of course, this situation already applies in certain contexts—such as European Medico-Legal Institutes—and to forensic pathology and those forensic sciences—such as forensic archaeology, anthropology, ecology and linguistics—whose inhabitants have long been ‘citizens of both the world of research and the world of practice’.

Roux et al. (63, 64), focus on the implications for trace evidence, including hairs, fibres, glass, paints and so on. They argue against a focus on sub-disciplinary knowledge at the expense of understanding of evidence of presence and activity at the crime scene, and—acknowledging wider socioeconomic factors—for forensic science research incorporating the whole judicial process from crime scene to court. They also argue for an improved epistemology—for research ‘on’ forensic science as well as ‘for’ it—see also Lawless (59) and Cole (60).

Roux et al. (63) further contend that forensic science be applied to “resolution of broader security problems”. This reflects the theme of the annual report of the Government Chief Scientific Advisor (21) who recommended going beyond the traditional boundaries into emerging areas such as digital evidence and cybercrime, and broader ones such as environmental protection and product authentication. It is not evident, however, that the Chief Scientific Advisor’s report has had any impact on forensic science research in the proposals for REF 2021—or that it was intended to do so, other than to encourage forensic scientists to look beyond their traditional boundaries and basic scientists to demonstrate the impact of their research in the forensic sphere.

In summary, most commentators accept a broad and inclusive understanding of forensic science research, including many complementary fields of knowledge. It is difficult to imagine how such a model could be delivered in the absence of forensic science embedded in the University mainstream, and the findings of this study do reflect a broad range of relevant on-going research activity in the UK Universities.

The importance of University-based forensic science research (see Fig. 2) has grown following the closure of the Forensic Science Service and despite the key recommendation of the Silverman Review that the government frameworks should require forensic science providers to carry out research and development.

Key recommendations of the Silverman Review also include the establishment of forensic science as a key priority for the Research Councils, and for the REF administrators to ensure they appoint assessors from the forensic science providers able to assess claims of impact of academic research. This raises the question as to how real the socio-economic impact in forensic science claimed in the numerous ICS with ‘forensic’ in the text really is.

The Silverman Review does not recommend a forensic science UOA, and seems to regard developing research by forensic science providers and by basic non-forensic scientists in Universities looking to demonstrate impact as sufficient. It states: “Firstly, by its nature, forensic science involves the application of research in areas right across the disciplinary spectrum. Secondly, although forensic

science is an important area of work, it does not have sufficient volume of activity to merit a Unit of Assessment of its own”.

Archaeology and Environmental Science, for example, also involve research areas across very broad disciplinary spectrums, but they are represented in the REF. This study does show a healthy volume of forensic outputs already submitted to RAE 2008 and REF 2014, supplemented by a growing body of University research published in the leading periodicals, some of which was returned in the audits.

Sadly, it is impossible to see how—in the UK context—the research culture called for by so many commentators (58-64) can be achieved without forensic science being properly included in REF or how solutions demanded in governmental and judicial inquiries reviewed in the Introduction can be met. These include research into economic questions (12) and validity of the sub-disciplines (21, 31, 32), establishment of research centres (19) and budgets (16), and Research Council support (17, 20).

## **5. Conclusions**

The study showed a broad spectrum of forensic research outputs were submitted to RAE 2008 and REF 2014, incorporating the traditional forensic sciences and relevant work in complementary disciplines. These findings further confirm the observations in the Silverman Review and Walport Report that identify the range of relevant research as a strength.

While outputs are skewed to non-traditional forensic subjects, the life sciences, engineering and computing disciplines are well represented. Whereas declining disciplines such as archaeology fell in overall volume, specifically ‘forensic’ outputs submitted in computer sciences grew by 740 percent. Submissions in chemistry were poor, an observation that is particularly disappointing given the role forensic science plays in supporting chemistry programmes that have recruited many ex-practitioners in recent years.

Due to the structure of these audits, however, all forensic outputs were returned as part of larger submissions, making it very difficult to associate the research quality ratings assigned to forensic outputs specifically. This was less so the case with Impact Case Studies, where submissions are fewer and it was possible to demonstrate highly rated socio-economic impact of clearly forensically relevant research. There were a large number of Impact Case Studies claiming forensic impact, however, and it is not clear whether the assessment panels of REF 2014 were sufficiently equipped to reliably assess these claims.

A study of UK affiliated journal articles published in leading forensic science periodicals over the duration of the two audits showed that the outputs submitted to RAE 2008 and REF 2014 were only a small proportion of the overall total produced. One reason for the disparity is that a substantial proportion of UK affiliated published research in forensic science is not produced by the Universities. This proportion was about 43 percent during the period of RAE 2008, falling to 27 per cent during REF 2014. The amount of University-based research doubled between the two periods, whereas the proportion produced by the private sector and by the Forensic Science Service—which closed in 2012—fell noticeably. Publication volume grew in University departments of forensic science, in chemistry—particularly in geosciences and toxicology, and in forensic archaeology and anthropology (Table 13).

While the number of outputs submitted in digital forensics grew substantially between RAE 2008 and REF 2014, these figures are not reflected in the forensic science journals, suggesting these periodicals are not capturing the growth of output in this area.



This study offers evidence that forensic science does have ‘sufficient volume of activity to merit a Unit of Assessment of its own’ relative to other disciplines, including those that also comprise research ‘across a wide disciplinary spectrum’. This is one of the strengths of forensic science, as it aims ultimately to contribute to public health and safety via crime reduction and prevention.

Without a UOA, specific assessment of the quality of forensic outputs is not possible. Even more seriously, there is no incentive for Universities to invest in research or research active staff in forensic science. Research Councils could offer funding programmes in forensic science, but without a research base to service these calls there will be limited demand—as reflected in two previous Engineering and Physical Sciences Research Council programmes, and few academic forensic scientists available to peer review grant applications and deliverables. It is difficult to see how research dealing with pattern analysis or crime science activity-level evidence alluded to by Margot could be meaningfully submitted and reliably assessed. This is a ‘vicious circle’.

The Silverman Review rightly states “The importance of the REF in driving and motivating the research of individual academics and groups, and in setting the agendas of universities, cannot be overestimated”. Having a forensic science explicitly incorporated in a UOA would encourage Universities to invest in specifically forensic research, supported by strong academic forensic science programmes and quality research active staff. These staff would be well placed to respond to Research Council funding calls in forensic science and to contribute to meaningful peer review of funding applications and deliverables. Direct assessment of forensic science research quality would provide a ‘reality check’ of the quality of research in comparison to the mainstream sciences and foster the development of academic work in the specifically-forensic sub-disciplines such as pattern and mark comparison, and analysis of activity level events at the crime scene. It would encourage theoretical and socio-economic studies of forensic science itself. It would also allow forensic science to make an explicit claim for a share of the large ‘QR’ funding pot. Overall, this would create a ‘virtuous circle’, which would substantially assist in the development of a forensic science research culture and compensate for the contraction in research produced by private providers, without placing ‘all the eggs in one basket’.

Whilst this study focuses on the UK, the implications may be relevant to other jurisdictions where governmental audits of University research quality are undertaken and, ultimately, to the need for forensic science to establish and maintain itself as a peer science in the academy and beyond.

## 6. References

1. Johnston, N., Politowski, B., Police funding, Briefing Paper Number 7279, 25 February 2016. House of Commons Library, London, 2016 (accessed on 9<sup>th</sup> May 2018 from <http://researchbriefings.files.parliament.uk/documents/CBP-7279/CBP-7279.pdf>).
2. Crown Prosecution Service Annual Report and Accounts 2015–16 (For the period April 2015–March 2016). Her Majesty’s Stationary Office, London, 2016 (accessed on 9<sup>th</sup> May 2018 from [https://www.cps.gov.uk/publications/docs/annual\\_report\\_2015\\_16.pdf](https://www.cps.gov.uk/publications/docs/annual_report_2015_16.pdf)).
3. Legal Aid Statistics in England and Wales: October to December 2015. Ministry of Justice, London, 2016 (accessed on 9<sup>th</sup> May 2018 from [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/512577/bulletin.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/512577/bulletin.pdf)).
4. National Audit Office Solicitor Survey for Criminal legal aid: Summary Report. National Audit Office, London, 2009 (accessed on 9<sup>th</sup> May 2018 from [https://www.nao.org.uk/wp-content/uploads/2009/11/091029\\_GfK\\_Survey.pdf](https://www.nao.org.uk/wp-content/uploads/2009/11/091029_GfK_Survey.pdf)).

5. Improving Service Delivery: The Forensic Science Service, Report by the Comptroller and Auditor General, HC 523 Session 2002-2003, 28 March 2003. National Audit Office, London, 2003 (accessed on 9<sup>th</sup> May 2018 from <https://www.nao.org.uk/wp-content/uploads/2003/03/0203523.pdf>).
6. Forensic Science Service to be wound up. BBC News, 14<sup>th</sup> December 2018 (accessed on 9<sup>th</sup> May 2010 from <http://www.bbc.co.uk/news/mobile/uk-11989225>).
7. The Home Office's oversight of forensic services: Briefing for the House of Commons Science and Technology Committee, December 2014. National Audit Office, London, 2014 (accessed on 9<sup>th</sup> May 2018 from <https://www.nao.org.uk/wp-content/uploads/2015/01/The-Home-Office%E2%80%99s-oversight-of-forensic-services.pdf>).
8. Tobin, L., Axe falls on forensics students, The Guardian, 14<sup>th</sup> March 2011 (accessed on 9<sup>th</sup> May 2018 from <https://www.theguardian.com/education/2011/mar/14/forensics-science-students-job-market>).
9. Probe into Radox Manchester 'manipulated' drug tests data. BBC News, 19th February 2017 (accessed on 9th May 2018 from <http://www.bbc.co.uk/news/uk-england-manchester-39020384>).
10. Smit, N.M., Morgan, R.M., Lagnado, D.A. A systematic analysis of misleading evidence in unsafe rulings in England and Wales, Science and Justice, 58 (2018) 128-137. <https://doi.org/10.1016/j.scijus.2017.09.005>.
11. May, J., Interim Report on the Maguire Case. Her Majesty's Stationary Office, London, 1990 (accessed on 9th May 2018 from [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/228724/0556.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/228724/0556.pdf)).
12. The Forensic Science Service, House of Commons Home Affairs Committee Report, HC 26, Her Majesty's Stationary Office, London, 1989.
13. McFarland, R., The Review of the Forensic Science Service—A Report. Her Majesty's Stationary Office, London, 2003.
14. The Scientific Response to Terrorism, House of Commons Science and Technology Committee Report, HC 415-I. Her Majesty's Stationary Office, London, 2003 (accessed on 9th May 2018 from <https://www.publications.parliament.uk/pa/cm200203/cmselect/cmsctech/415/415.pdf>).
15. Forensic Science on Trial, House of Commons Science and Technology Committee Report, HC 96-I. Her Majesty's Stationary Office, London, 2005 (accessed on 9th May 2018 from <https://www.publications.parliament.uk/pa/cm200405/cmselect/cmsctech/96/96i.pdf>).
16. The Forensic Science Service, House of Commons Science and Technology Committee Report, HC 555. Her Majesty's Stationary Office, London, 2011 (accessed on 9th May 2018 from <https://www.publications.parliament.uk/pa/cm201012/cmselect/cmsctech/855/855.pdf>).
17. Forensic science, House of Commons Science and Technology Committee Report, HC 610. Her Majesty's Stationary Office, London, 2013 (accessed on 9th May 2018 from <https://www.publications.parliament.uk/pa/cm201314/cmselect/cmsctech/610/610.pdf>).
18. Forensic Science Strategy, House of Commons Science and Technology Committee Report, HC 501. Her Majesty's Stationary Office, London, 2016 (accessed on 9th May 2018 from <https://www.publications.parliament.uk/pa/cm201617/cmselect/cmsctech/501/501.pdf>).
19. Runciman Viscount Runciman of Doxford, The Royal Commission on Criminal Justice—Report, Cm 2263. Her Majesty's Stationary Office, London, 1993 (accessed on 9th May 2018 from

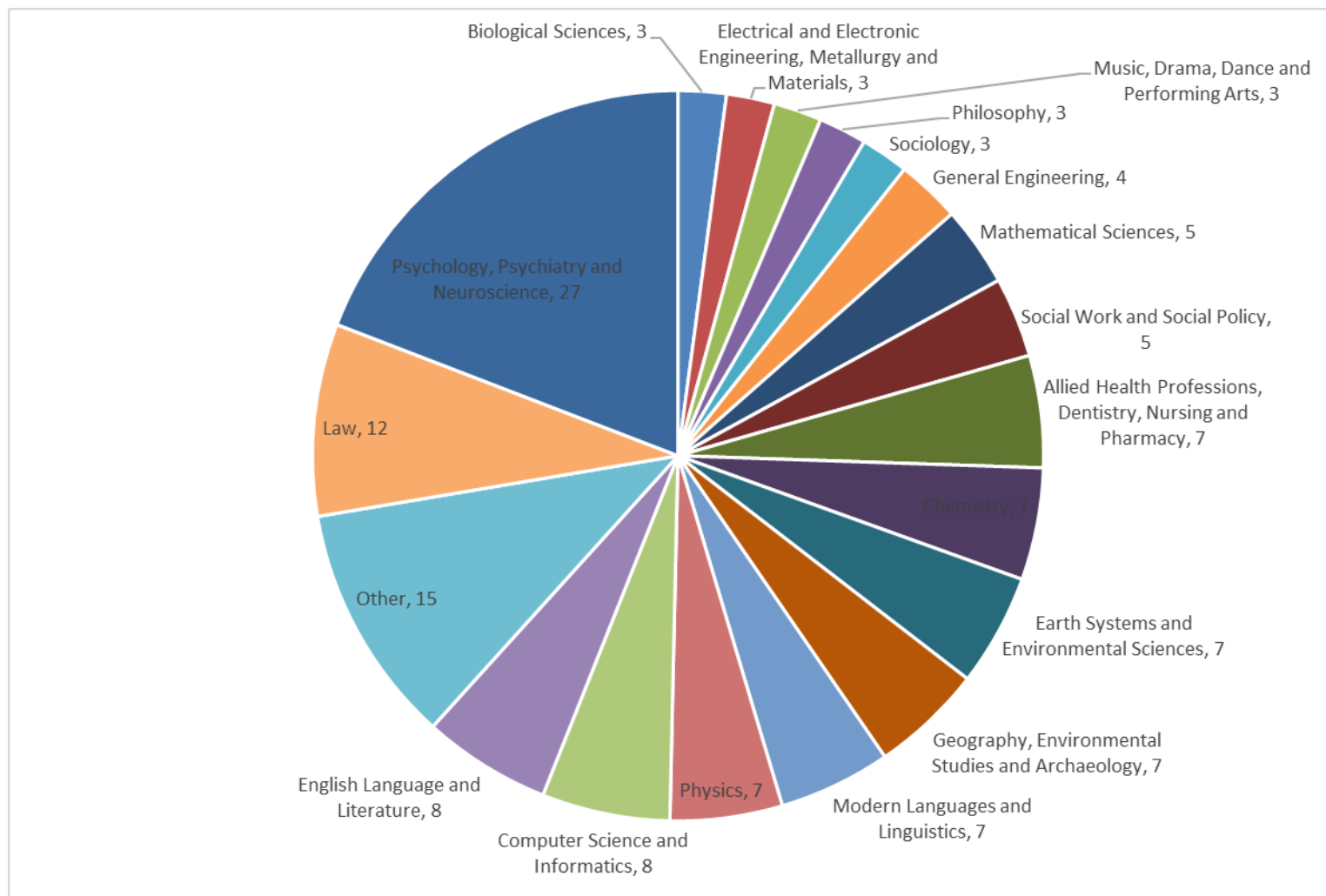
- [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/271971/263.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/271971/263.pdf)).
20. Silverman, B., Research and Development in Forensic Science: A Review. Home Office, London, 2011 (accessed on 9th May 2018 from [https://www.gov.uk/government/uploads/system/uploads/attachment\\_data/file/118916/forensic-science-review-report.pdf](https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/118916/forensic-science-review-report.pdf)).
  21. Leveson, B., Review of Efficiency in Criminal Proceedings. Judiciary of England and Wales, London, 2015 (accessed on 9th May 2018 from <https://www.judiciary.gov.uk/wp-content/uploads/2015/01/review-of-efficiency-in-criminal-proceedings-20151.pdf>).
  22. Annual Report of the Government Chief Scientific Adviser 2015. Forensic Science and Beyond: Authenticity, Provenance and Assurance, The Government Office for Science, London, 2005 (accessed on 9th May 2018 from [https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment\\_data/file/506461/gs-15-37a-forensic-science-beyond-report.pdf](https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/506461/gs-15-37a-forensic-science-beyond-report.pdf)).
  23. Ambage, N. V., The Origins and Development of the Home Office Forensic Science Service, 1931-1967. Unpublished PhD Thesis, University of Lancaster, Lancaster, UK, 1987 (accessed on 9th May 2018 from <http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.379193>).
  24. Ward, J., Origins and development of forensic medicine and forensic science in England 1823-1943. Unpublished PhD Thesis, Open University, Milton Keynes, UK, 1993 (accessed on 9th May 2018 from <http://oro.open.ac.uk/18983/1/pdf180.pdf>).
  25. Evison, M.P. Departmental review 1991-1998: University of Sheffield, Department of Forensic Pathology, University of Sheffield, Department of Forensic Pathology, 1998 (accessed on 9th May 2018 from [https://www.researchgate.net/publication/276026175\\_Departmental\\_review\\_1991-1998\\_University\\_of\\_Sheffield\\_Department\\_of\\_Forensic\\_Pathology](https://www.researchgate.net/publication/276026175_Departmental_review_1991-1998_University_of_Sheffield_Department_of_Forensic_Pathology)).
  26. Forensic body to dissect provision, Times Higher Education, 10<sup>th</sup> February 2006 (accessed on 9th May 2018 from <https://www.timeshighereducation.com/news/forensic-body-to-dissect-provision/201244.article>).
  27. Educational Accreditation Application Process, Chartered Society of Forensic Sciences UK, 2017 (accessed on 9th May 2018 from <http://www.csofs.org/Accreditation>).
  28. Clark, L., Thousands of students being 'hoodwinked' into taking courses for jobs they will never get, Mail Online, 30<sup>th</sup> August 2012.
  29. Auranan, M., Nieminen, M., University research funding and publication performance—An international comparison, Research Policy 39 (2010) 822-834. <https://doi.org/10.1016/j.respol.2010.03.003>.
  30. Butler, E. Public Choice – A Primer. Institute of Economic Affairs, London UK, 2012 (accessed on 17th July 2017 from <https://iea.org.uk/wp-content/uploads/2016/07/IEA%20Public%20Choice%20web%20complete%2029.1.12.pdf>).
  31. Strengthening Forensic Sciences in the United States: A Path Forward, National Academies of Sciences USA. National Academies Press, Washington DC, 2009 (accessed on 17<sup>th</sup> July 2017 from <https://www.ncjrs.gov/pdffiles1/nij/grants/228091.pdf>).
  32. Forensic Science in Criminal Courts: Ensuring Scientific Validity of Feature-Comparison Methods, Report to the President. Executive Office of the President of the United States, President's Council of Advisors on Science and Technology, Washington DC, 2016 (accessed on 17<sup>th</sup> July 2017 from

- [https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast\\_for\\_ensic\\_science\\_report\\_final.pdf](https://obamawhitehouse.archives.gov/sites/default/files/microsites/ostp/PCAST/pcast_for_ensic_science_report_final.pdf)).
33. Pullin, A. S., Stewart, G. B., Guidelines for Systematic Review in Conservation and Environmental Management, *Conservation Biology* 20 (6) (2006) 1647-1656. <http://dx.doi.org/10.1111/j.1523-1739.2006.00485.x>.
  34. Belcher, B. M., Rasmussen, K. E., Kemshaw, M. R., Zornes, D. A., Defining and assessing research quality in a transdisciplinary context, *Research Evaluation*, 25 (2015) 1-17. <http://dx.doi.org/10.1093/reseval/rvv025>.
  35. <http://www.rae.ac.uk/Submissions/> (accessed 9<sup>th</sup> May 2018).
  36. <http://results.ref.ac.uk/Results> (accessed 9<sup>th</sup> May 2018).
  37. <http://www.rae.ac.uk/submissions/intro.aspx> (accessed 9<sup>th</sup> May 2018).
  38. <http://www.ref.ac.uk/2014/results/intro/> (accessed 9<sup>th</sup> May 2018).
  39. <http://www.rae.ac.uk/aboutus/quality.asp> (accessed 9<sup>th</sup> May 2018).
  40. <http://www.ref.ac.uk/2014/results/intro/> (accessed 9<sup>th</sup> May 2018).
  41. <http://www.rae.ac.uk/aboutus/uoa.asp> (accessed 9<sup>th</sup> May 2018).
  42. <http://www.ref.ac.uk/2014/pubs/2012-01/> (accessed 9<sup>th</sup> May 2018).
  43. <http://www.rae.ac.uk/submissions/outstore/CSV-ANSI/all%20submissions.zip> (accessed 9<sup>th</sup> May 2018).
  44. <http://results.ref.ac.uk/DownloadSubmissions/ByForm/REF2> (accessed 9<sup>th</sup> May 2018).
  45. <http://www.ref.ac.uk/2014/pubs/201401/> (accessed on 9<sup>th</sup> May 2018 as REF\_01\_2014\_-\_results\_full\_document.pdf).
  46. <http://www.rae.ac.uk/submissions/default.aspx> (accessed 9<sup>th</sup> May 2018).
  47. <http://results.ref.ac.uk/Search> (accessed 9<sup>th</sup> May 2018).
  48. <http://impact.ref.ac.uk/CaseStudies/> (accessed 9<sup>th</sup> May 2018).
  49. <http://www.ref.ac.uk/2014/pubs/2011-02/> (accessed 9<sup>th</sup> May 2018).
  50. [http://www.ref.ac.uk/2014/media/ref/content/pub/unitsofassessmentandrecruitmentofexpertpanels/01\\_10.pdf](http://www.ref.ac.uk/2014/media/ref/content/pub/unitsofassessmentandrecruitmentofexpertpanels/01_10.pdf) (accessed 9<sup>th</sup> May 2018).
  51. <https://www.ncbi.nlm.nih.gov/pubmed/advanced> (accessed 9<sup>th</sup> May 2018).
  52. <http://www.ref.ac.uk/2014/results/analysis/comparisonwith2008raeresults/> (accessed 9<sup>th</sup> May 2018).
  53. Braddick, M., Will the study of archaeology soon become a thing of the past?, *The Guardian*, 19<sup>th</sup> February 2013 (accessed on 9<sup>th</sup> May 2018 from <https://www.theguardian.com/higher-education-network/blog/2013/feb/19/archaeology-funding-student-decline-future>).
  54. Reid, W. A., Pathology in the Medical Curriculum in the United Kingdom, *Journal of Veterinary Medical Education*, 34 (4) (2007) 390-395. <https://doi.org/10.3138/jvme.34.4.390>.
  55. Domizio, P., The Changing Role of Pathology in the Undergraduate Curriculum, in: P. Hall, N.A. Wright (Eds.) *Understanding Disease: A Centenary Celebration of the Pathological Society*. Wiley: London, 2006, pp. 137-152, (accessed on 9<sup>th</sup> May 2018 from <https://www.pathsoc.org/files/history/c12.pdf>).
  56. [http://www.ref.ac.uk/media/ref%2C2021/downloads/REF%202017\\_04%20Decisions.pdf](http://www.ref.ac.uk/media/ref%2C2021/downloads/REF%202017_04%20Decisions.pdf) (accessed 9<sup>th</sup> May 2018).

57. <https://www.timeshighereducation.com/fr/news/ref-2014-winners-who-performed-best/2017591.article> (accessed 9<sup>th</sup> May 2018).
58. Mnookin, J., Cole, S.A., Dror, I., Fisher, B.A.J., Houck, M., Inman, K., et al., The Need for a Research Culture in the Forensic Sciences, Legal Studies Research Paper No. 5-2011, Pennsylvania State University Law, 2011.
59. Lawless, C., Forensic Science – A Sociological Introduction. Routledge, London, 2016.
60. Cole, S., Forensic culture as epistemic culture: The sociology of forensic science, Studies in History and Philosophy of Biological and Biomedical Sciences, 44(1), (2013) 36-46. <https://doi.org/10.1016/j.shpsc.2012.09.003>.
61. Margot, P., Commentary on The Need for a Research Culture in the Forensic Sciences, UCLA Law Review, 58 (2011), 789-793 (accessed on 9<sup>th</sup> May 2018 from <https://www.uclalawreview.org/pdf/58-3-5.pdf>).
62. Linacre, A., Towards a research culture in the forensic sciences, Australian Journal of Forensic Sciences, 45(4) (2013) 381-388. <https://doi.org/10.1080/00450618.2012.738246>.
63. Roux, C., Talbot-Wright, B., Robertson, J., Crispino, F., Ribaux, O., The end of the (forensic science) world as we know it? The example of trace evidence, Philosophical Transactions of the Royal Society B, 370 (2015) <https://doi.org/10.1098/rstb.2014.0260>.
64. Roux, C., Crispino, F., Ribaux, O., From Forensics to Forensic Science, Current Issues in Criminal Justice, 7 (2012) (accessed on 9<sup>th</sup> May 2018 from <http://www.austlii.edu.au/cgi-bin/viewdoc/au/journals/CICrimJust/2012/16.html>).

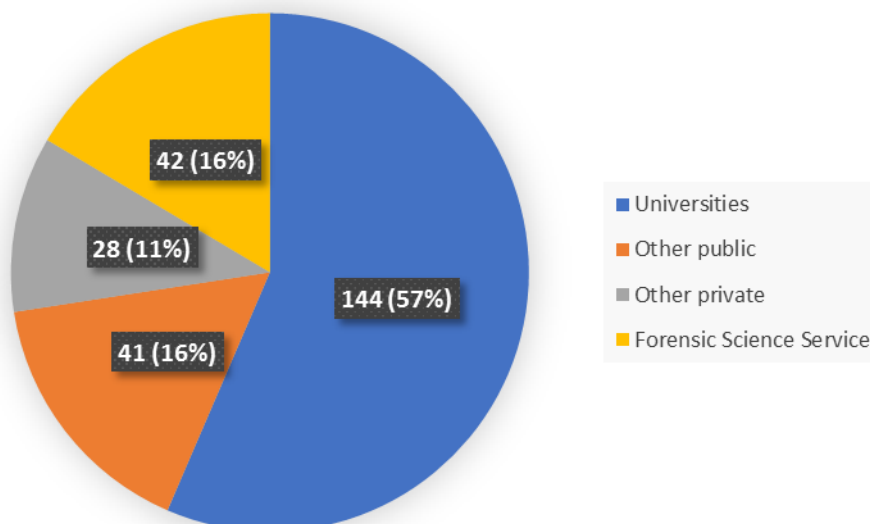
**Figure 1**

Pie chart illustrating the distribution of REF 2014 Impact Case Studies containing 'forensic' in the text by Unit of Assessment (UOAs with fewer than three studies are collated under 'Other', see Methods).

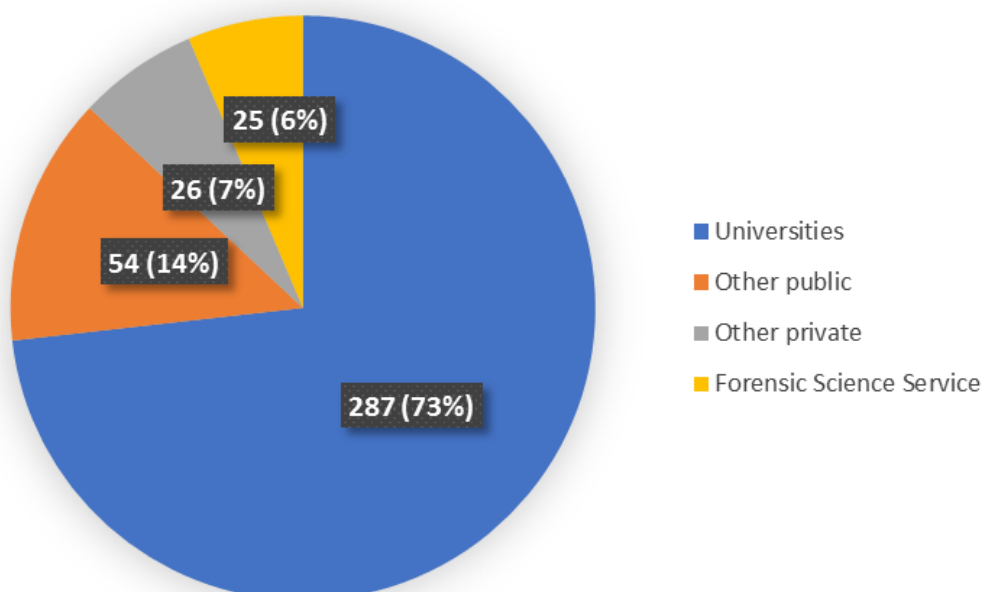


**Figure 2**

Pie charts illustrating the distribution of UK-affiliated publications in four leading forensic science journals during the RAE 2008 and REF 2014 periods by organisation (see Methods)



**RAE 2008**



**REF 2014**

**Table 1**

Summary of numbers of records found in searches of all research outputs using various search terms in the Long Title, Short Title and Publisher spreadsheet columns (RAE 2008).

Spreadsheet Column	Search Term								
	Forensic	Archaeological	Archeological	Archaeology	Archeology	Environmental	Pathological	Pathology	Craniofacial
Long title	97	193	2	324	5	1202	114	148	21
Short title	13	64	0	201	1	116	1	1	0
Publisher	95	301	2	450	0	1481	0	496	25
<b>Total outputs</b>	<b>186</b>	<b>509</b>	<b>4</b>	<b>886</b>	<b>5</b>	<b>2584</b>	<b>115</b>	<b>634</b>	<b>45</b>

Source: <http://www.rae.ac.uk/submissions/outstore/CSV-ANSI/all%20submissions.zip>; RA2.csv.



**Table 2**

Summary of numbers of records found in searches of all research outputs using various search terms in the Title, Publisher and Volume Title spreadsheet columns (REF 2014).

Spreadsheet Column	Search Term								
	Forensic	Archaeological	Archeological	Archaeology	Archeology	Environmental	Pathological	Pathology	Craniofacial
Title	111	149	3	235	2	1004	86	218	16
Publisher	0	28	2	70	0	2	0	0	0
Volume Title	100	213	0	335	1	1477	2	296	9
<b>Total outputs</b>	<b>197</b>	<b>365</b>	<b>5</b>	<b>581</b>	<b>3</b>	<b>2348</b>	<b>88</b>	<b>504</b>	<b>24</b>

Source: <http://results.ref.ac.uk/DownloadSubmissions/ByForm/REF2>.

**Table 3**

Summary of numbers of research groups found in searches of all research group names using various search terms.

	Search Term								
	Forensic	Archaeological	Archeological	Archaeology	Archeology	Environmental	Pathological	Pathology	Craniofacial
RAE2008	6	0	0	8	2	80	0	12	1
REF2014	9	2	0	8	0	61	0	3	1

Sources: <http://www.rae.ac.uk/submissions/outstore/CSV-ANSI/all%20submissions.zip>; RA2.csv and <http://results.ref.ac.uk/DownloadSubmissions/ByForm/REF2>.

**Table 4**

Research groups found in searches of the spreadsheet Research Group Name column using the term 'forensic' (RAE 2008).

<b>Institution</b>	<b>Unit of Assessment</b>	<b>Research Group</b>
Leeds Trinity & All Saints	Psychology	Forensic Psychology Group
Anglia Ruskin University	Geography and Environmental Studies	Forensic Science
University of Portsmouth	Psychology	The Centre for Research in Forensic Psychology
University of Leicester	Other Hospital Based Clinical Subjects	Forensic Pathology
University of Liverpool	Psychology	Applied Social and Forensic Psychology
Queen Mary, University of London	Psychiatry, Neuroscience and Clinical Psychology	Forensic Mental Health

Source: <http://www.rae.ac.uk/submissions/outstore/CSV-ANSI/all%20submissions.zip>; ResearchGroup.csv.

**Table 5**

Summary of forensic outputs submitted to RAE 2008 by output type.

<b>Output Type</b>		<b>Outputs submitted with 'forensic' in the article or volume title</b>	<b>Additional outputs submitted by forensic research groups, located by research group code</b>	<b>Additional outputs submitted by forensic research groups, located manually</b>	<b>Total Forensic Outputs</b>
A	Authored book	8	1	0	9
B	Edited book	2	0	0	2
C	Chapter in book	21	0	0	21
D	Journal article	151	55	4	210
E	Conference contribution	2	0	0	2
H	Website content	1	7	0	8
N	Research report for external body	1	0	0	1
R	Scholarly edition	0	0	0	0
T	Other form of assessable output	0	0	0	0
<b>Total Forensic Outputs</b>		<b>186</b>	<b>63</b>	<b>4</b>	<b>253</b>

**Table 6**

Research groups and Impact Case Studies (ICS) found in searches of the spreadsheet Research Group Name column using the term 'forensic' (REF 2014).

<b>Institution</b>	<b>Unit of Assessment</b>	<b>Research Group</b>	<b>ICS</b>	<b>Forensic ICS</b>	<b>Forensic ICS %</b>
Middlesex University	Psychology, Psychiatry and Neuroscience	Forensic Psychology	2	0	0
University of Birmingham	Psychology, Psychiatry and Neuroscience	Forensic Psychology	5	2	40
University of Liverpool	Psychology, Psychiatry and Neuroscience	Forensic and Investigative Psychology	4	1	25
University of Central Lancashire	Psychology, Psychiatry and Neuroscience	Forensic Psychology	3	2	67
University of Huddersfield	Biological Sciences	Forensic Biology	2	0	0
University of Kent	Psychology, Psychiatry and Neuroscience	Forensic Psychology	4	3	75
University of Lincoln	Psychology, Psychiatry and Neuroscience	Forensic and Clinical	2	0	0
University of Portsmouth	Psychology, Psychiatry and Neuroscience	Forensic Psychology	4	2	50
University of Surrey	Computer Science and Informatics	Multimedia and Forensics (MSF)	3	0	0

Source: <http://results.ref.ac.uk/DownloadSubmissions/ByForm/REF2>.

**Table 7**

Impact Case Studies submitted via research groups with 'forensic' in the research group name (REF2014), with number of associated forensic outputs, total studies submitted to the associated institutional submission / unit of assessment and research quality profile assigned.

<b>Institution</b>	<b>Unit of Assessment</b>	<b>Impact Case Study Title</b>	<b>Forensic Outputs</b>	<b>Total Studies</b>	<b>3-4* Rating</b>
University of Birmingham	Psychology, Psychiatry and Neuroscience	Sex offenders- Ensuring public safety and improving the effectiveness of treatment through the development of an algorithm to match sex offenders with appropriate probation-based treatment*	1	5	100
University of Central Lancashire	Psychology, Psychiatry and Neuroscience	Developing policies and procedures for managing bullying and aggression in secure services*	1	3	100
University of Central Lancashire	Psychology, Psychiatry and Neuroscience	Providing software, training and support to the police to allow them to identify criminal suspects using facial-composite images*	3	3	100
University of Kent	Psychology, Psychiatry and Neuroscience	Developing assessment and treatment practices for female sexual offenders*	1	4	100
University of Kent	Psychology, Psychiatry and Neuroscience	The benefits of polygraph testing for sexual offenders*	0	4	100
University of Kent	Psychology, Psychiatry and Neuroscience	The first comprehensive theory-based treatment of firesetting*	1	4	100
University of Liverpool	Psychology, Psychiatry and Neuroscience	Providing Evidence Based Solutions in Criminal Justice and Critical Incidents*	5	4	100
University of Portsmouth	Psychology, Psychiatry and Neuroscience	Cognitive research leads to improved lie detection processes and training adopted by professionals in forensic, intelligence, security and commercial settings*	2	3	100
University of Portsmouth	Psychology, Psychiatry and Neuroscience	Promoting justice, protecting victims and supporting witnesses- The impact of the Self-Administered Interview (SAI©) in investigative contexts*	2	3	100

Source: <http://results.ref.ac.uk/Results>.

**Table 8**

Impact Case Studies with 'forensic' in the title (REF 2014) with number of associated forensic outputs, total studies submitted to the associated institutional submission / unit of assessment and research quality profile assigned.

<b>Institution</b>	<b>Unit of Assessment</b>	<b>Impact Case Study Title</b>	<b>Forensic Outputs</b>	<b>Total Studies</b>	<b>3-4* Rating</b>
Aston University	Modern Languages and Linguistics	Forensic linguistics- improving the delivery of justice	1	3	73.3
Bangor University	Earth Systems and Environmental Sciences	New DNA forensics tools improve sustainable fisheries management and reduce wildlife crime	3	5	90.0
City University London	Mathematical Sciences	FINEX- A probabilistic expert system for forensic identification	1	3	80.0
Imperial College London	Biological Sciences	Revolutionising 'omics and forensics research- conception and development of Q-TOF mass spectrometry	0	11	92.7
Keele University	Computer Science and Informatics	Classification within forensic datasets	1	2	40.0
Leeds Beckett University	Architecture, Built Environment and Planning	Improving the as-constructed energy performance of dwellings through building forensics	2	3	36.7
Liverpool John Moores University	Law	Improving The Commissioning and Production of Psychiatric Reports for Sentencing and The Training of Forensic Psychiatrists Through Good Practice Guidance	-	2	100.0
Queen Mary University of London	Geography, Environmental Studies and Archaeology	Regulating the forensic use of bioinformation	1	4	80.0
Queen's University Belfast	Geography, Environmental Studies and Archaeology	Investigating Crime- Geoforensics at Work	1	4	50.0
University of Bristol	Chemistry	CH6- Molecular and Isotope 'Fingerprinting' to Enhance Food Quality Assurance, Forensic Approaches and Wider Public Interest in Chemistry through Archaeology	2	5	88.6
University of Dundee	Art and Design: History, Practice and Theory	Craniofacial Depiction for Forensic Identification and Archaeological Investigation	-	5	100.0

University of Edinburgh(joint submission with Heriot-Watt University*)	Mathematical Sciences	Bayesian statistical methods applied to the quantification of forensic evidence	-	10	84.0
University of Glasgow	Earth Systems and Environmental Sciences	Forensic, Cultural and Renewable Energy Impacts of Radiocarbon	-	4	80.0
University of Leicester	Biological Sciences	Tools for analysing human Y-chromosome diversity-impact of DNA testing on the development of genetic genealogy and male-specific forensic analysis	1	4	80.0
University of Leicester	Earth Systems and Environmental Sciences	Uranium isotope 'forensic' testing in relation to Gulf War Illness	1	4	80.0
University of Portsmouth	Psychology, Psychiatry and Neuroscience	Cognitive research leads to improved lie detection processes and training adopted by professionals in forensic, intelligence, security and commercial settings	-	3	100.0
University of Warwick	Biological Sciences	A Novel Way to Detect Infection Status of Wildlife likely to have Bovine Tuberculosis ('Badger Infection Forensics')	-	5	84.0
University of York	Modern Languages and Linguistics	LAN01 - Forensic speaker comparison	4	1	100.0

Source: <http://results.ref.ac.uk/Search?uoald=&orgId=&formId=REF3b&searchText=Forensic>.



**Table 9**

Summary of forensic outputs submitted to REF 2014 by output type.

<b>Output Type</b>	<b>Outputs submitted with 'forensic' in the article or volume title</b>	<b>Additional outputs submitted by forensic research groups, located by index code</b>	<b>Additional outputs submitted by forensic research groups, located manually</b>	<b>Additional outputs from impact case studies located manually via submissions associated with forensic research groups</b>	<b>Additional outputs submitted as part of 'forensic' impact case studies</b>	<b>Total Forensic Outputs</b>
A Authored book	10	0	0		3	13
B Edited book	1	0	0		1	2
C Chapter in book	6	0	0			6
D Journal article	173	41	35	5	9	263
E Conference contribution	3	0	2		1	6
H Website content	1	0	0			1
N Research report for external body	0	0	0		2	2
R Scholarly edition	2	0	0			2
T Other form of assessable output	1	0	0			1
<b>Total Forensic Outputs</b>	<b>197</b>	<b>41</b>	<b>37</b>	<b>5</b>	<b>16</b>	<b>296</b>

**Table 10**

Forensic submissions to RAE2008 and REF2014 by Unit of Assessment based on REF2014 classifications.

Unit of Assessment (RAE 2008)	Institutions	Outputs	Unit of Assessment (REF 2014)	Institutions	Outputs
<i>Precursors to REF 2014 Unit</i>	-	-	Clinical Medicine	1	1
<i>Precursors to REF 2014 Unit</i>	-	-	Public Health, Health Services and Primary Care	2	2
Nursing and Midwifery	17	30	Allied Health Professions, Dentistry, Nursing and Pharmacy	11	30
Psychology	20	90	Psychology, Psychiatry and Neuroscience	15	82
Biological Sciences	2	4	Biological Sciences	6	14
Agriculture, Veterinary and Food Science	-	-	Agriculture, Veterinary and Food Science	1	1
Earth Systems and Environmental Sciences	1	1	Earth Systems and Environmental Sciences	3	5
Chemistry	2	5	Chemistry	2	3
Physics	-	-	Physics	1	2
Statistics and Operational Research	5	5	Mathematical Sciences	2	2
Computer Science and Informatics	5	5	Computer Science and Informatics	18	37
Mechanical, Aeronautical and Manufacturing Engineering	2	4	Aeronautical, Mechanical, Chemical and Manufacturing Engineering	3	9
Electrical and Electronic Engineering	4	4	Electrical and Electronic Engineering, Metallurgy and Materials	3	5
Civil Engineering	1	1	Civil and Construction Engineering	1	1
General Engineering and Mineral & Mining Engineering	2	3	General Engineering	9	13
Architecture and the Built Environment	-	-	Architecture, Built Environment and Planning	2	3
Geography and Environmental Studies	12	32	Geography, Environmental Studies and Archaeology	6	12
Business and Management Studies	4	6	Business and Management Studies	3	4
Law	6	7	Law	7	16
Social Work and Social Policy & Administration	13	23	Social Work and Social Policy	13	27
Sociology	9	11	Sociology	3	3
Anthropology	1	1	Anthropology and Development Studies	-	-
Education	1	1	Education	1	1

Linguistics	2	9	Modern Languages and Linguistics	5	8
English Language and Literature	3	3	English Language and Literature	3	4
History	2	2	History	3	4
Theology, Divinity and Religious Studies	1	1	Theology and Religious Studies	-	-
Art and Design	2	5	Art and Design: History, Practice and Theory	3	4
Music	-	-	Music, Drama, Dance and Performing Arts	1	1
Communication, Cultural and Media Studies	-	-	Communication, Cultural and Media Studies, Library and Information Management	1	2
<b>Total</b>	<b>118</b>	<b>253</b>		<b>129</b>	<b>296</b>

**Table 11**

Summary descriptive statistics of RAE 2008 and REF 2014 forensic research output submissions, and research quality profile and staff head count numbers assigned to the associated institutional submission / unit of assessment.

	RAE 2008			REF 2014			Change (Percent)		
	Maximum	Minimum	Average	Maximum	Minimum	Average	Maximum	Minimum	Average
Percent Quality Outputs (3-4* ranked)	85.00	0.00	46.75	97.50	14.80	64.91	14.71	-	38.84
Staff Members	214.59	1.00	34.64	219.00	5	37.52	2.06	400.00	8.33
Forensic Outputs	34	1	2.16	22	1	2.29	-35.29	0.00	6.11
Forensic Outputs/Staff Member	4.000	0.005	0.160	1.106	0.005	0.113	-72.36	-2.01	-29.70
Forensic Outputs/ Percent Quality Outputs	1.133	0.000	0.069	0.384	0.010	0.041	-66.12	-	-40.49
Forensic Contribution†	1.000	0.001	0.040	0.276	0.001	0.028	-72.36	-2.01	-29.70
Forensic Outputs to 3-4* Ranking (%)‡	10.714	0.000	1.078	15.84	0.080	1.559	47.81	-	44.53

† Proportion of 'forensic' outputs out of the possible total (calculated as 4 outputs per staff member submitted)

‡ Ratio (%) of percent quality outputs to the proportion of 'forensic' outputs out of the possible total

**Table 12**

Summary of outputs submitted to four leading forensic science periodical journals during the RAE 2008 and REF 2014 periods by output type.

Discipline	RAE 2008 Period					REF 2014 Period				
	Forensic Science International	Forensic Science International: Genetics	Journal of Forensic Sciences	Science & Justice	Total	Forensic Science International	Forensic Science International: Genetics	Journal of Forensic Sciences	Science & Justice	Total
Case Reports	4	0	2	2	8	15	1	6	3	25
Clinical Trial	1	0	1	0	2	0	0	0	0	0
Comparative Study	10	2	5	0	17	8	5	8	6	27
Correction	1	0	0	0	1	0	0	0	0	0
Evaluation Studies	4	0	0	0	4	0	2	0	1	3
Historical Article	0	0	0	1	1	1	0	0	1	2
Journal Articles	114	6	47	55	222	128	39	84	84	335
<b>Total Forensic Outputs</b>	<b>134</b>	<b>8</b>	<b>55</b>	<b>58</b>	<b>255</b>	<b>152</b>	<b>47</b>	<b>98</b>	<b>95</b>	<b>392</b>

**Table 13**

Summary of UK affiliated outputs submitted to four leading forensic science periodical journals during the RAE 2008 and REF 2014 periods by discipline.

<b>Discipline</b>	<b>RAE 2008</b>	<b>REF 2014</b>
Anthropology and Archaeology	12	23
Applied Sciences	2	15
Biosciences	25	22
Chemistry and Toxicology	15	57
Computer Science	1	2
Dentistry	18	7
Engineering	9	9
Forensic Medicine	20	13
Forensic Science	17	94
Geography and Environment	10	16
Mathematics and Statistics	11	6
Psychology	3	19
Social Sciences	1	4
<b>Total UK Outputs</b>	<b>144</b>	<b>287</b>

**Table S1**

Table of Comma Separated Value (CSV) files downloaded as part of the RAE 2008 submission and results data.

<b>File Name</b>	<b>Description</b>
Institution.csv	Indexed table of institutions making submissions to RAE2008
JointSubmission.csv	Indexed table of submissions made jointly by pairs or groups of institutions
MultipleSubmission.csv	Indexed table of institutions making more than one submission to a single unit of assessment
OutputType.csv	Indexed table of classifications of outputs submitted
Profile.csv	Indexed table of results of RAE rating profiles for each submission
RA0.csv	Indexed table of staff profiles associated with each submission
RA1.csv	Indexed table of staff associated with each submission
RA2.csv	Table of outputs submitted indexed by institution, joint submission, multiple submission, unit of assessment, output type, and research group codes
RA3a.csv	Indexed table of research staff and students associated with each submission
RA3b.csv	Indexed table of research studentships associated with each submission
RA3bSource.csv	Indexed table of research studentship funding sources
RA4.csv	Indexed table of research funding income associated with each submission
RA4Source.csv	Indexed table of research funding sources
ResearchGroup.csv	Indexed table of research groups submitted
UnitOfAssessment.csv	Indexed table of units of assessment

Source: <http://www.rae.ac.uk/submissions/outstore/CSV-ANSI/all%20submissions.zip>.

**Table S2**

Table of worksheets included as part of the REF 2014 submission and results data.

<b>Worksheet name</b>	<b>Description</b>
Output	Table of outputs submitted, indexed by joint submission, institution, unit of assessment, output type, research group, submission and submission profile codes
JointSubmission	Indexed look-up table of submissions made jointly by pairs or groups of institutions
Institution	Indexed look -up table of institutions making submissions to REF2014
UnitOfAssessment	Indexed look -up table of units of assessment
OutputType	Indexed look -up table of classifications of outputs submitted
ResearchGroup	Indexed look -up table of research groups submitted
Submission	Indexed look -up table of submissions made by each institution including joint and multiple submissions
Submission profile	Indexed look -up table of results of REF2014 rating profiles for each submission
Category4Staff	Indexed look -up table of number of FTE Category 4 staff submitted by each institution to each unit of assessment

Source: <http://results.ref.ac.uk/DownloadFile/Form/REF2/excel>.



**Table S3. Forensic submissions to RAE2008 and REF2014 by Institution and Unit of Assessment based on REF2014 classifications, with associated staff head count and research quality profile assigned.**

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
44 Psychology			1	4.0	45	-			
32 Geography and Environmental Studies			4	8.4	20	-			
-					20 Law		3	10.2	30.6
-					35 Music, Drama, Dance and Performing Arts		1	13.8	27.7
Anglia Ruskin University	2	5				2	4		
-					11 Computer Science and Informatics		1	18.2	52.9
<b>50 European Studies</b>		<b>3</b>	<b>33.1</b>	<b>20</b>	<b>28 Modern Languages and Linguistics</b>		<b>1</b>	<b>18.5</b>	<b>49.2</b>
Aston University	1	3				2	2		
-					11 Computer Science and Informatics		1	34.6	43.1
University of Bedfordshire						1	1		
-					20 Law		1	27.2	70.0
41 Sociology		2	24.6	35	-				
Birkbeck College	1	2				1	1		
<b>44 Psychology</b>		<b>2</b>	<b>45.1</b>	<b>80</b>	<b>4 Psychology, Psychiatry and Neuroscience</b>		<b>11</b>	<b>40.8</b>	<b>82.4</b>
33 Archaeology		2	18.2	50	-				
University of Birmingham	2	4				1	11		
40 Social Work and Social Policy & Administration		1	6.0	20	-				
Birmingham City University	1	1							
-					4 Psychology, Psychiatry and Neuroscience		1	5.3	29.2
University of Bolton						1	1		
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy		2	21.4	49.4
<b>33 Archaeology</b>		<b>3</b>	<b>7.5</b>	<b>35</b>	<b>17 Geography, Environmental Studies and Archaeology</b>		<b>2</b>	<b>29.5</b>	<b>55.6</b>
Bournemouth University	1	3				2	4		
13 Pharmacy		1	20.0	55	-				
<b>33 Archaeology</b>		<b>6</b>	<b>20.0</b>	<b>50</b>	<b>17 Geography, Environmental Studies and Archaeology</b>		<b>1</b>	<b>12.8</b>	<b>56.1</b>
University of Bradford	2	7				1	1		
-					8 Chemistry		2	58.6	97.5
-					10 Mathematical Sciences		1	83.5	81.2
-					15 General Engineering		1	123.4	91.9
University of Bristol						3	4		
-					12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering		1	63.3	64.3
-					15 General Engineering		1	63.5	59.7
Brunel University London						2	2		
-					4 Psychology, Psychiatry and Neuroscience		1	76.0	92.0
14 Biological Sciences		1	213.7	60	-				
22 Statistics and Operational Research		1	16.0	75	-				
-					11 Computer Science and Informatics		1	54.6	83.7
33 Archaeology		1	45.4	60	-				
38 Law		1	83.3	60	-				
41 Sociology		1	21.0	55	-				
<b>58 Linguistics</b>		<b>6</b>	<b>10.0</b>	<b>50</b>	<b>28 Modern Languages and Linguistics</b>		<b>1</b>	<b>96.5</b>	<b>77.2</b>
University of Cambridge	6	11				3	3		

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
<b>12 Allied Health Professions and Studies</b>		<b>1</b>	<b>10.6</b>	<b>5</b>	<b>3 Allied Health Professions, Dentistry, Nursing and Pharmacy</b>		<b>5</b>	<b>13.9</b>	<b>47.2</b>
Canterbury Christ Church University	1	1				1	5		
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy		1	49.6	59.1
<b>44 Psychology</b>		<b>1</b>	<b>30.9</b>	<b>20</b>	<b>4 Psychology, Psychiatry and Neuroscience</b>		<b>15</b>	<b>17.6</b>	<b>41.7</b>
<b>33 Archaeology</b>		<b>2</b>	<b>5.0</b>	<b>20</b>	<b>17 Geography, Environmental Studies and Archaeology</b>		<b>3</b>	<b>8.0</b>	<b>35.5</b>
40 Social Work and Social Policy & Administration		1	14.1	40	-				
-					28 Modern Languages and Linguistics		1	10.6	70.0
University of Central Lancashire	3	4				4	20		
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy		7	23.0	43.2
40 Social Work and Social Policy & Administration		4	10.8	15	-				
University of Chester	1	4				1	7		
11 Nursing and Midwifery		4	48.6	70	-				
<b>36 Business and Management Studies</b>		<b>3</b>	<b>94.5</b>	<b>55</b>	<b>19 Business and Management Studies</b>		<b>2</b>	<b>78.3</b>	<b>82.2</b>
41 Sociology		1	27.2	45	-				
City University, London	3	8				1	2		
-					4 Psychology, Psychiatry and Neuroscience		1	14.0	39.0
Coventry University						1	1		
-					12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering		7	156.7	82.3
25 General Engineering and Mineral & Mining Engineering		2	42.9	30	-				
Cranfield University	1	2				1	7		
-					11 Computer Science and Informatics		1	24.7	51.9
-					22 Social Work and Social Policy		1	20.1	45.3
De Montfort University						2	2		
<b>40 Social Work and Social Policy &amp; Administration</b>		<b>2</b>	<b>35.0</b>	<b>60</b>	<b>22 Social Work and Social Policy</b>		<b>1</b>	<b>24.1</b>	<b>67.7</b>
42 Anthropology		1	33.6	55	-				
University of Durham	2	3				1	1		
-					5 Biological Sciences		1	44.0	79.8
18 Chemistry		1	30.0	55	-				
University of East Anglia	1	1				1	1		
44 Psychology		1	10.2	20	-				
University of East London	1	1							
-					29 English Language and Literature		1	13.9	57.4
Edge Hill University						1	1		
41 Sociology		1	43.7	60	-				
University of Essex	1	1							
25 General Engineering and Mineral & Mining Engineering B Camborne School of Min		1	16.2	35	-				
-					30 History		1	41.5	76.9
University of Exeter	1	1				1	1		
32 Geography and Environmental Studies		4	12.0	15	-				
University of Gloucestershire	1	4							

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
-					4 Psychology, Psychiatry and Neuroscience	2		33.3	72.2
-					34 Art and Design: History, Practice and Theory	2		31.3	56.7
Goldsmiths' College						2	4		
-					4 Psychology, Psychiatry and Neuroscience	1		11.5	41.9
University of Greenwich						1	1		
-					5 Biological Sciences	6		13.0	35.4
-					9 Physics	2		12.0	54.8
-					22 Social Work and Social Policy	3		41.8	49.7
-					30 History	2		14.3	62.1
University of Huddersfield						4	13		
-					19 Business and Management Studies		1	43.8	49.0
University of Hull						1	1		
-					15 General Engineering		1	33.5	96.0
Imperial College London						1	1		
-					7 Earth Systems and Environmental Sciences	3		10.2	55.0
-					11 Computer Science and Informatics	3		5.0	58.3
40 Social Work and Social Policy & Administration			1	39.5	65	-			
Keele University	1	1				2	6		
-					4 Psychology, Psychiatry and Neuroscience		13	33.1	64.3
-					11 Computer Science and Informatics		1	29.1	70.1
24 Electrical and Electronic Engineering			1	16.0	40	-			
-					15 General Engineering		1	24.0	75.0
40 Social Work and Social Policy & Administration			1	55.7	70	-			
University of Kent	2	2				3	15		
13 Pharmacy			1	44.3	55	-			
9 Psychiatry, Neuroscience and Clinical Psychology			1	214.6	55	-			
-					23 Sociology		1	18.9	72.2
King's College London	2	2				1	1		
22 Statistics and Operational Research			1	21.7	60	-			
40 Social Work and Social Policy & Administration			3	42.3	60	-			
41 Sociology			1	29.8	60	-			
57 English Language and Literature			1	29.0	60	-			
Lancaster University	4	6							
38 Law			2	35.2	55	-			
57 English Language and Literature			1	49.4	65	-			
University of Leeds	2	3							
-					16 Architecture, Built Environment and Planning		2	18.1	39.2
Leeds Beckett University						1	2		
44 Psychology			4	1.0	0	-			
Leeds Trinity & All Saints	1	4							

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
4 Other Hospital Based Clinical Subjects		4	17.0	30	-				
-					5 Biological Sciences	1	37.4	87.3	
-					7 Earth Systems and Environmental Sciences	1	21.8	89.3	
-					8 Chemistry	1	21.4	82.1	
-					19 Business and Management Studies	1	59.6	52.7	
<b>40 Social Work and Social Policy &amp; Administration A Criminology</b>		<b>2</b>	<b>10.0</b>	<b>35</b>	<b>22 Social Work and Social Policy</b>	<b>2</b>	<b>12.0</b>	<b>84.8</b>	
University of Leicester	2	6				5	6		
<b>44 Psychology</b>		<b>2</b>	<b>5.8</b>	<b>25</b>	<b>4 Psychology, Psychiatry and Neuroscience</b>	<b>3</b>	<b>12.8</b>	<b>35.7</b>	
University of Lincoln	1	2				1	3		
-					2 Public Health, Health Services and Primary Care	1	31.3	58.8	
12 Allied Health Professions and Studies		4	37.0	40	-				
<b>44 Psychology</b>		<b>34</b>	<b>28.0</b>	<b>30</b>	<b>4 Psychology, Psychiatry and Neuroscience</b>	<b>2</b>	<b>33.0</b>	<b>68.5</b>	
-					16 Architecture, Built Environment and Planning	1	22.2	79.0	
University of Liverpool	2	38				3	4		
63 Art and Design A University of the Arts		3	206.2	50	-				
University of the Arts London	1	3							
24 Electrical and Electronic Engineering		1	33.0	60	-				
33 Archaeology		2	61.7	60	-				
<b>40 Social Work and Social Policy &amp; Administration</b>		<b>4</b>	<b>7.0</b>	<b>75</b>	<b>22 Social Work and Social Policy</b>	<b>3</b>	<b>12.8</b>	<b>75.6</b>	
-					25 Education A Institute of Education	1	219.0	67.9	
University College London	3	7				2	4		
-					5 Biological Sciences	1	172.9	77.7	
University College London (joint submission with Birkbeck College)						1	1		
-					20 Law	1	62.9	84.7	
-					23 Sociology	1	24.8	73.3	
London School of Economics and Political Science						2	2		
-					4 Psychology, Psychiatry and Neuroscience	1	9.8	34.3	
London South Bank University						1	1		
-					11 Computer Science and Informatics	2	17.2	47.1	
36 Business and Management Studies		1	57.4	60	-				
41 Sociology		1	47.2	45	-				
Loughborough University	2	2				1	2		
11 Nursing and Midwifery		1	57.9	85	-				
9 Psychiatry, Neuroscience and Clinical Psychology		1	39.5	50	-				
-					5 Biological Sciences	4	144.6	72.4	
40 Social Work and Social Policy & Administration		1	13.0	45	-				
University of Manchester	3	3				1	4		
<b>12 Allied Health Professions and Studies A Allied Health Research</b>		<b>1</b>	<b>24.7</b>	<b>20</b>	<b>3 Allied Health Professions, Dentistry, Nursing and Pharmacy</b>	<b>1</b>	<b>61.4</b>	<b>61.8</b>	
-					11 Computer Science and Informatics	1	11.5	64.9	
Manchester Metropolitan University	1	1				2	2		

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
-					4 Psychology, Psychiatry and Neuroscience	7	13.1	52.2	
36 Business and Management Studies		1	38.8	30	-				
-					22 Social Work and Social Policy	5	51.4	45.4	
Middlesex University	1	1				2	12		
4 Other Hospital Based Clinical Subjects		1	92.8	65	-				
-					4 Psychology, Psychiatry and Neuroscience	1	51.6	80.7	
-					11 Computer Science and Informatics	1	27.5	80.0	
41 Sociology		1	21.6	50	-				
Newcastle University	2	2				2	2		
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy	3	13.4	33.3	
-					12 Aeronautical, Mechanical, Chemical and Manufacturing Engineering	1	6.8	14.8	
University of Northampton						2	4		
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy	4	44.2	73.3	
-					11 Computer Science and Informatics	2	13.0	58.1	
-					20 Law	7	13.7	50.0	
-					22 Social Work and Social Policy	4	30.6	49.5	
University of Northumbria at Newcastle						4	17		
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy B Nursing and Allied he	1	37.8	77.7	
9 Psychiatry, Neuroscience and Clinical Psychology		1	31.5	35	-				
University of Nottingham	1	1				1	1		
-					22 Social Work and Social Policy	1	9.5	35.7	
41 Sociology		1	42.3	55	-				
Open University	1	1				1	1		
-					2 Public Health, Health Services and Primary Care	1	47.7	87.0	
23 Computer Science and Informatics		1	55.8	80	11 Computer Science and Informatics	2	73.5	86.7	
32 Geography and Environmental Studies		3	28.5	70	17 Geography, Environmental Studies and Archaeology B Geography and Environm	2	53.9	79.8	
40 Social Work and Social Policy & Administration		1	22.8	70	-				
-					30 History	1	130.1	74.2	
University of Oxford	3	5				4	6		
-					36 Communication, Cultural and Media Studies, Library and Information Management	2	7.3	66.7	
Oxford Brookes University						1	2		
44 Psychology		23	16.0	25	4 Psychology, Psychiatry and Neuroscience	22	19.9	57.3	
36 Business and Management Studies		1	56.8	35	-				
-					22 Social Work and Social Policy	1	23.1	56.8	
University of Portsmouth	2	24				2	23		
10 Dentistry		1	33.7	75	-				
9 Psychiatry, Neuroscience and Clinical Psychology		8	8.7	40	-				
Queen Mary, University of London	2	9							

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
22 Statistics and Operational Research			1	7.7	35	-			
33 Archaeology			1	19.0	65	-			
38 Law			1	21.9	60	-			
40 Social Work and Social Policy & Administration			1	8.9	50	-			
University of Reading	4	4							
-					1 Clinical Medicine		1	64.0	84.2
10 Dentistry			1	31.4	70	-			
9 Psychiatry, Neuroscience and Clinical Psychology			1	20.0	40	-			
28 Mechanical, Aeronautical and Manufacturing Engineering			1	30.2	75	-			
24 Electrical and Electronic Engineering B Electronic and Electrical Engineering			1	38.0	60	-			
38 Law			1	31.6	50	-			
40 Social Work and Social Policy & Administration			1	26.6	65	-			
University of Sheffield	6	6					1	1	
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy		2	34.5	90.7
44 Psychology			1	39.1	60	-			
22 Statistics and Operational Research			1	28.0	65	-			
-					11 Computer Science and Informatics		2	44.2	68.4
-					13 Electrical and Electronic Engineering, Metallurgy and Materials		2	84.3	96.9
32 Geography and Environmental Studies			1	32.5	55	-			
-					22 Social Work and Social Policy		3	41.0	85.5
-					29 English Language and Literature		1	24.8	72.0
University of Southampton	3	3					5	10	
44 Psychology			2	8.0	5	-			
23 Computer Science and Informatics			1	34.0	25	-			
University of Sunderland	2	3							
12 Allied Health Professions and Studies			1	61.7	60	-			
23 Computer Science and Informatics			1	16.2	50	11 Computer Science and Informatics	9	19.4	57.7
-					13 Electrical and Electronic Engineering, Metallurgy and Materials		2	83.1	89.7
41 Sociology			2	21.4	55	-			
University of Surrey	3	4					2	11	
-					15 General Engineering		1	13.0	57.4
Teesside University							1	1	
-					11 Computer Science and Informatics		2	24.4	94.9
University of Warwick							1	2	
-					3 Allied Health Professions, Dentistry, Nursing and Pharmacy		1	45.4	70.2
-					15 General Engineering		1	14.0	94.1
-					22 Social Work and Social Policy		1	19.8	37.2
University of the West of England, Bristol							3	3	
23 Computer Science and Informatics			1	20.3	25	-			
University of Westminster	1	1							

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
-					4 Psychology, Psychiatry and Neuroscience		1	8.5	33.3
University of Winchester						1	1		
-					11 Computer Science and Informatics		1	34.8	84.2
-					28 Modern Languages and Linguistics		3	14.1	76.3
University of York						2	4		
44 Psychology		3	10.0	15	-				
-					15 General Engineering		5	14.2	34.8
University of Abertay Dundee	1	3				1	5		
<b>14 Biological Sciences</b>		<b>3</b>	<b>65.0</b>	<b>65</b>	<b>5 Biological Sciences</b>		<b>1</b>	<b>73.2</b>	<b>89.5</b>
-					17 Geography, Environmental Studies and Archaeology		1	14.3	64.2
-					20 Law		1	17.0	59.6
<b>63 Art and Design</b>		<b>2</b>	<b>52.4</b>	<b>55</b>	<b>34 Art and Design: History, Practice and Theory</b>		<b>1</b>	<b>44.5</b>	<b>57.6</b>
University of Dundee	2	5				4	4		
9 Psychiatry, Neuroscience and Clinical Psychology		1	89.9	65	-				
<b>38 Law</b>		<b>1</b>	<b>48.7</b>	<b>55</b>	<b>20 Law</b>		<b>2</b>	<b>54.0</b>	<b>64.0</b>
University of Edinburgh	2	2				1	2		
-					15 General Engineering		1	91.8	91.0
University of Edinburgh (joint submission with Heriot-Watt University)						1	1		
44 Psychology		1	6.8	5	-				
23 Computer Science and Informatics		1	26.7	20	-				
Napier University	2	2							
-					10 Mathematical Sciences		1	43.0	83.6
-					11 Computer Science and Informatics		1	41.6	76.0
-					15 General Engineering		1	84.0	95.8
University of Glasgow						3	3		
18 Chemistry		4	51.4	70	-				
University of Glasgow / University of Strathclyde	1	4							
-					22 Social Work and Social Policy		1	14.4	55.4
Glasgow Caledonian University						1	1		
-					34 Art and Design: History, Practice and Theory		1	52.8	46.1
Glasgow School of Art						1	1		
22 Statistics and Operational Research		1	30.0	45	-				
Heriot-Watt University / University of Edinburgh	1	1							
61 Theology, Divinity and Religious Studies		1	3.6	10	-				
UHI Millennium Institute	1	1							
12 Allied Health Professions and Studies		1	51.8	5	-				
Queen Margaret University Edinburgh	1	1							
38 Law		1	9.6	5	-				
Robert Gordon University	1	1							
-					28 Modern Languages and Linguistics		2	32.8	63.7
University of St Andrews						1	2		

RAE Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*	REF Unit of Assessment	#UOAs	#Outs	#Staff	#4-3*
44 Psychology		1	17.0	30	-				
-					14 Civil and Construction Engineering	1	20.2	80.3	
-					22 Social Work and Social Policy	1	15.7	59.7	
University of Strathclyde	1	1				2	2		
-					20 Law	1	16.5	47.4	
Aberystwyth University						1	1		
-					6 Agriculture, Veterinary and Food Science	1	18.2	66.8	
17 Earth Systems and Environmental Sciences		1	28.4	60	7 Earth Systems and Environmental Sciences	1	35.4	85.7	
Bangor University (joint submission with Aberystwyth University)	1	1				2	2		
10 Dentistry		1	27.6	65	-				
44 Psychology		1	59.4	70	-				
28 Mechanical, Aeronautical and Manufacturing Engineering		3	25.6	65	-				
-					23 Sociology	1	29.5	77.9	
<b>57 English Language and Literature</b>		<b>1</b>	<b>44.2</b>	<b>60</b>	<b>29 English Language and Literature</b>	<b>2</b>	<b>24.0</b>	<b>86.8</b>	
Cardiff University	4	6				2	3		
12 Allied Health Professions and Studies		1	28.7	15	-				
University of Wales Institute, Cardiff	1	1							
11 Nursing and Midwifery		3	22.6	35	-				
-					11 Computer Science and Informatics	1	13.5	21.3	
45 Education		1	1.0	0	-				
University of South Wales*	2	4				1	1		
<b>11 Nursing and Midwifery</b>		<b>3</b>	<b>33.7</b>	<b>35</b>	<b>3 Allied Health Professions, Dentistry, Nursing and Pharmacy B Nursing</b>	<b>3</b>	<b>14.2</b>	<b>78.8</b>	
29 Metallurgy and Materials		1	15.0	60	-				
62 History		1	18.0	50	-				
Swansea University	3	5				1	3		
-					11 Computer Science and Informatics	5	21.2	69.2	
-					13 Electrical and Electronic Engineering, Metallurgy and Materials	1	33.8	88.7	
27 Civil Engineering		1	24.1	75	-				
<b>32 Geography and Environmental Studies</b>		<b>3</b>	<b>20.0</b>	<b>50</b>	<b>17 Geography, Environmental Studies and Archaeology</b>	<b>3</b>	<b>30.8</b>	<b>55.0</b>	
62 History		1	30.5	60	-				
Queen's University Belfast	3	5				3	9		
Total	117	253				129	296		

\* University of Glamorgan/University of Wales, Newport

NB Staff head count and percent 3-4\* rated outputs refer to overall submission to Unit of Assessment

Institutional submissions in the same Unit of Assessment in both RAE2008 and REF2014 are given in red font



Explanatory Note: The Table lists forensic submissions by Institution using the relevant HEFCE code (not shown), beginning with Anglia Ruskin University in England and ending with Queen's University Belfast in Northern Ireland. Within each Institution, details of submissions are shown only where they were made, listed by the REF 2014 UOA code, beginning with 1 Clinical Medicine and ending with 36 Communication, Cultural and Media Studies, Library and Information Management. Submissions to RAE 2008 are shown on the left and to REF 2014 on the right. If submissions were made to only one exercise, the corresponding submission to the other exercise will be blank and details will only be shown on the right or left side of the Table. Where Institutions made submissions to corresponding UOAs in both exercises, details will be present on both the left and right sides of the Table. These are shown in red font.