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Is Forensic Science In Danger of Extinction?

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Abstract

Observations of modern day forensic science has prompted asking the question of whether this field is in danger of extinction. Although there have undoubtedly been meaningful advancements in analytical capabilities, we have overlooked several unintended practical and philosophical consequences. This article addresses three main areas of concern: the declining role of the generalist in an era of increased specialization, the role of education in preparing the next generation of forensic scientists, and the implementation of advanced instrumentation with a focus on statistical significance and field deployable instrumentation.

Highlights

- Modern technology requires specialization, but the generalist remains essential.
- Forensic science education must stress the importance of holistic philosophies.
- Increased analytical sensitivities requires emphasis on the interpretive context.
- Field deployable instrumentation cannot replace the scientist at the scene.

Keywords

Forensic Science, Generalist, Specialist, Field Deployable Instrumentation, Education, Training

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1. Introduction

With a collective knowledge gained over many years, comprised of considerable education, training and casework experience, we have witnessed extensive and profound change within the forensic science profession. Much of this has been beneficial to our field, however some of these same changes have had unintended consequences. Certain advances technologically have allowed casework scientists the ability to obtain information to a level previously unobtainable. The advent of modern day DNA technology, as an example, can in most respects be considered a boon for our profession. Other advancements in chemical instrumentation and analytical techniques allow us to obtain levels of evidentiary information not dreamed of just a few decades ago. We have often said that we have been extremely lucky to have come of “forensic age” during this explosion in technology.

Much has been learned by observing the introduction of DNA analysis stumble through many of its early iterations and attempts as a casework testing procedure. Unfortunately the passage of time dims memory, and many newer criminalists may not be aware of cases such as the Castro case [1]. In this instance the court DID NOT allow the associative DNA results obtained by what was then Lifecodes Corporation, in as evidence. Judge J. Scheindlin, in a Bronx, NY courtroom, rather than making a perfunctory decision about admission or exclusion, he wisely brought together opposing experts to come to a consensus on the scientific validity of the evidence. The experts concluded that there was insufficient supporting data, as well as a lack of appropriate testing controls, to establish the technique as reliable enough to associate a defendant as the source of the material. Judge Scheindlin did allow for analytical results that exculpated a source. He thus avoided a situation where testing results obtained from a poorly defined methodology could falsely incriminate an individual. In the realm of error types (Type I false inclusion and Type II false exclusion) and their classifications, this would prevent a "Type 1" error from occurring; an instance where an innocent individual is implicated for something he/she did not do. It was only after enduring these kinds of growing pains that this particular methodology did attain such widespread general acceptance, now being considered by some to be the "gold standard" of forensic evidence. It is unfortunate that the practice of bringing experts together to reach a consensus with respect to the reliability and relevance of forensic evidence is not seen as a general model to be emulated within the adversary system. This consensus cited in the Castro case above demonstrated its superior effectiveness at providing the courts with the best evidence in an adversary system. This case has also served as the impetus for the implementation of sound and validated lab procedures. Inexplicably, it has not contributed toward the desired scientific consensus seeking approach toward evidence interpretation and reporting.

2. Specialist vs. Generalist Capabilities

The field of forensic science appears to have forgotten the legacy of early criminalists such as Archibald Reiss [2], Edmond Locard [3] and Paul Leland Kirk [4-7]. Each of these scientists provided both philosophical and scientific approaches in the interpretation of traces and other evidence at crime scenes. Although forensic scientists recognize Locard's exchange principle which is expressed in it oversimplified form as 'every contact leaves a trace', his additional contributions are often overlooked. An underlying commonality for each of these criminalists was the value they placed on the importance of comprehensive scientific expertise at the scene. As recently defined [8], the generalist is "a scientist with broad knowledge of criminalistics and physical evidence. Ideally, such a scientist would have in-depth specialist knowledge and expertise in one or a limited number of relevant areas." In the United Kingdom, the "Byford Scientist" is a concept that is somewhat akin to the generalist scientist concept being discussed here [9]. For decades, the rise of the specialists to the detriment of the generalist scientist philosophy has been a considerable concern [8, 10-14]. The fear is that in the absence of the oversight of the generalist scientist, non-scientist law enforcement personnel and attorneys are filling the void on the front and back-ends of an investigation and litigation.

A generalist scientist provides valuable contributions to a crime scene investigation through scientific education, training and experience. As Louis Pasteur famously stated, "in the fields of observation chance favors only the prepared mind" [15]. The prepared mind in this case is the scientifically prepared generalist, who knowledgeably uses the scientific method with associated hypothesis development and testing to inform aspects of the investigation based on the physical evidence. Recognizing the loss of awareness of the generalist philosophy among the younger generations of forensic scientists, Hunter [11] attempted to enlighten newer scientists to the value of the early legacy of the generalist scientist:

> *The GENERALIST. A criminalist that can look at the evidence as a whole and see a full picture. We need to develop and maintain the criminalist that can pick up those various pieces of the puzzle, parts of the whole spliced together by the specialist, and fit them together and create a the [sic] whole image.*

There is clearly an important role for the specialist. The nature of instrumentation in today's laboratories requires more sophisticated knowledge and training, which has led to increased specialization by forensic scientists. But as discussed above, the generalist forensic scientist still remains absolutely essential, despite a decline in the appreciation for the concept. In staffing a moderate sized lab, it may be sufficient to have several generalist/specialists with complementary specialties. In a larger laboratory, there is the luxury of having a greater number of specialists as a resource available for the generalist scientist to serve as case managers to assign specific analyses. Without recognizing the interdependent relationship between the generalist and specialist scientists for forensic science investigations, the field as a whole is doomed to extinction. The disturbing trend of the transformation of forensic laboratories into inflexible production-line testing facilities is already underway. This is akin to a clinical laboratory staffed by technicians where there is a menu of available tests to order and a predefined finite list of possible results. By way of contrast, the forensic science inquiry for understanding the information encoded in the infinite number of possible relevant traces at a crime scene is open ended.

3. Educating/Training the Next Generation of Forensic Scientists.

If forensic science is in danger of extinction, how much of that can be attributed to the manner in which it is taught in colleges, universities and casework laboratories to our future practitioners? There is a corollary question: to what extent has the increased specialization in the field of forensic science permeated our forensic pedagogy? Unfortunately, many higher education programs in the United States seem to be structured to train specialists rather than educate generalist forensic scientists. Where this is the case, we are perpetuating the previously discussed problem through our current education scheme.

When reflecting on early forensic science training and education, its various techniques/methodologies were taught in a combination of classroom learning and in an apprenticeship/mentorship fashion. The latter was a key component in understanding the nuances of the field of forensic science. It is our contention that quality mentoring should remain an essential component of a thorough generalist education. Mentorship can be provided to young forensic science students in a variety of forms, by incorporating laboratory internships and by requiring supervised student research with veteran criminalists. Along with higher education, workplace mentorship by experienced scientists is key to the creation of quality criminalists. There are many who recognize and appreciate the importance of mentorship, but unfortunately it is easy to forget its value, and historically it has been missing from many laboratory training programs.

While the importance of specialist education is recognized given the current scientific complexities with evidence analysis, all too often the previously discussed points are missing within these types of programs. It is imperative for forensic scientists to have a broad understanding of a range of scientific knowledge. Forensic evidence does not exist in isolation. An example that illustrates this point would be to blindly sample or swab a reddish-brown stain on an item of clothing without appropriate documentation of its size, shape and distribution which is needed for bloodstain pattern analysis. This has happened in several high profile cases, with the hindsight that a general knowledge in evidence awareness and the interconnectedness of various types of evidence would have prevented these situations from occurring. In our experience, similar parallels can be made with other types of evidence, such as the firearms examiner washing off the bullet thus destroying trace evidence which has occurred in several cases. It is important for forensic science education to stress the importance of holistic philosophies as it pertains to the selection and analysis of traces.

Additionally, the education of forensic scientists needs to emphasize the significance of analytical queries in addition to training them on the steps of the technique: the nature of this questioning is what crosses into the realm of being a trained forensic scientist as opposed to a technician. An awareness of not just **HOW** to perform a given test or analysis, but **WHY** it's being done is critical. This particular concept of **WHY** is critical to the development of the forensic scientist's approach, but unfortunately appears to be fading in this age of increased specialization and accreditation. This is the primary distinction among forensic scientists and molecular biologists, or chemists, or any other "hard science" scientist. This form of critical evaluation is what defines the practice of forensic science. By applying scientific concepts and utilizing the scientific method, an assessment is made which ultimately leads to a decision as to a path to follow.

4. Implications of Advances in Instrumentation

In most respects, forensic science and the analysis of physical traces from crime scenes has greatly benefitted from the technological boom experienced over the last 25 years. Two areas where this is of particular note are in evidentiary statistical assessments and detection sensitivities, are discussed below.

In the field of forensic biology the ability to provide very strong statistical match probability statements has dramatically expanded. From results indicating a probability that a stain question is associated with approximately 40% of the population (ABO blood type A), to the probability of selecting a random individual in the population expressing a particular DNA profile being on the order of 1 in 10^{30}, the increase in discrimination potential has reached staggering new heights. This is clearly large in relation to the world population which has reached over 7.5 billion in 2018. There is a broad range of not-genetically testable evidence types for which a myriad of approaches and associative techniques can be very useful. For some of these, the strength of the potential association rivals that of the discrimination of genetic typing, and for others there is a need for more data in order to produce statistical assessments. Detailed fracture matches in a number of different media (e.g. paper, glass, tape, automotive paint, etc…) provide an example with virtual certainty of association such as in DNA typing. The fields of trace and pattern evidences (markedly in glass analysis, fingerprint, firearms and toolmarks) are developing statistical methods in attempts to quantify associations similarly to those used in DNA analyses. However, for some of these, this is complicated by the potential lack of knowledge about the independence of features (as opposed to genetic loci on different chromosomes) and an un-assessable disequilibrium of manufactured materials (such as fibers and automotive paint).

This is not to depreciate the value and utility of associations that are not supported by such large numbers. Without regard to the actual number, the significance of an association depends on the overall case circumstances. There is an important role for less than absolute associations of traces. Since the advent of DNA typing, there is an almost default expectation of astronomical numbers on the part of investigators, attorneys, judges and jurors. Anything less than this is often erroneously viewed as 'junk science'. There are individual diverse traces such as paint, fibers, degraded biological samples, etc… which in combination provide complimentary information that can create a valuable associations and reconstruction of events. For example, consider a homicide case where the victim's body has a degraded foreign blood stain on her clothing with only a few interpretable loci associated with the suspect and excluding the victim. When this is combined with automotive carpet fabric of the same type as that found in the suspect's vehicle, it provides powerful evidence for association of the suspect with the victim. Illusory certainty provided by large probability statistical estimates is not required for the resolution of all associative evidence issues.

Advances in technology have also allowed forensic scientists to obtain information from samples of certain types and sizes never attempted in prior years. Increased sensitivities and limits of detection often associated with these technological advances have opened this door widely for forensic scientists. In forensic DNA analysis, increased sensitivities have provided DNA information derived from no more than several nucleated cells. Forensic scientists can similarly detect illicit drugs in a fingermark friction ridge deposit at such a low level that cocaine is found in the latent prints of non-users [16] and identify the dyes/pigments in a single fiber [17]. These improvements are some of the most desirable of analytical characteristics; maximizing the amount of information from a minimal amount of physical evidence. The issue of whether these techniques can be ***too sensitive*** is discussed below.

It is often said that if something appears too good to be true, it often is. There are several implications of possible concern regarding these technological advances. In the area of forensic DNA analysis, one interesting issue has arisen. As stated earlier, forensic scientists using the Polymerase Chain Reaction (PCR) have obtained viable DNA results from just several nucleated cells, but is that necessarily the boon it appears to be? This increase in sensitivity has allowed for the detection of DNA stemming from just a few epithelial cells, ushering in the age of "touch

DNA" (also called "low level", "low template" or "low copy number" DNA analysis). On its surface, this provides powerful associative information on a level never before seen. However, the challenges of interpretation implications of the results of these kinds of associations can be far more complex than previously encountered. For example, in the investigation of a homicide, an innocent person's DNA was found under the victim's fingernails [18]. Ultimately this was determined to be the result of a multiple order transfer by the ambulance paramedics as opposed to direct contact during the commission of the murder. Had the accused not had an "airtight" alibi by being in the hospital during the commission of the crime, this secondary transfer of DNA would have likely gone unrecognized. Although this would not have affected this case directly or others like it involving multiple order transfers, it demonstrates the value of elimination DNA databases. This case illustrates the need for practitioners in the field to look beyond just the analytical identification data presented and understand the underlying nature of transfers and persistence. This strikes to the very core of the Locard exchange principle, or to quote Paul Kirk "Only human failure to find it, study and understand it, can diminish its value." [4] Currently, the field is meeting the challenge of Kirk's insight in that we have the capability of finding minute transfers, but have not sufficiently addressed his concerns about issues of understanding evidence significance.

There have been vastly increased demands for laboratory services as a result of numerous causes, two of which are the exponential technological growth along with an awareness of increased laboratory capabilities. Various forms of evidence associated with certain types of cases, such as property crimes, are now routinely submitted to forensic laboratories for analysis, whereas in the past they would not have been considered. This potentially contributes to the resolution of investigative issues that could have remained unsolved. It has, however, its own unintended consequences of episodic and undirected growth. First, an increased number of samples submitted for analysis puts additional costs on the laboratory (e.g. consumables, instrumentation, equipment maintenance) to maintain the level of services demanded. This has not necessarily resulted in a commensurate increase in resources such as additional scientists or enhanced laboratory funding. Secondly, and perhaps more significantly, it reinforces a "shotgun" approach for evidence collection. This is exemplified by the unfortunate practice of non-scientist scene investigators naively and non-selectively sampling/swabbing large numbers of items at the scene or on the evidence, and 'letting the lab sort it out'. This runs counter to the goal of knowledge-based informed selection that is an essential component of the principles of forensic science. The lack of general criminalistics evidence awareness of the significance of physical evidence, both in the laboratory and at the crime scene, only serves to promote this flawed and disappointing practice. Careful specimen selection can often be the key to avoiding unnecessarily complicated mixtures and limiting contamination, where the inclusion of extraneous materials which may not have evidentiary significance could, in addition to increasing lab load, complicate the interpretation. In the case of DNA analysis, this could be a complex mixture where the bulk of multi-allelic activity has no significance to the question(s) at hand. An additional benefit to informed selective collection is that by scrutinizing the specimen prior to analysis, other specimen-specific information can be obtained. Also, by employing informed specimen collection (e.g., cutting, lifting or scraping as opposed to swabbing), unnecessary dilution can be avoided. Coupled with the increased sensitivities discussed earlier, a failure to utilize selective documentation, preservation and collection can lead to the inclusion of a tremendous amount of obscuring material, delaying the recognition of relevant details and unnecessarily complicating the interpretation of the results.

The evolving technology of sophisticated field deployable instrumentation suggests that in the near future it will rival the capabilities of traditional laboratory benchtop instruments. These range from portable infrared spectrometers and gas chromatography/mass spectrometers to rapid DNA analysis units utilizing chip-based microfluidic technologies. Although they currently do not have the sensitivity of their laboratory counterparts, it is anticipated that they soon will. These instruments, with the included software technology, may allow a non-scientist investigator to obtain laboratory-quality analytical data in a short time frame. Furthermore, although computers can be programmed to complete complex tasks, the temptation of a non-scientist to naively accept and promote an interpretation generated by an artificial intelligence algorithm, there is a serious danger to having computers replace the higher-order human reasoning required for crime scene reconstruction. A leading computer scientist reflecting on the capabilities of artificial intelligence stated [19]:

> *"If it's a fixed set of rules, with players acting according to preexisting behaviors, then it becomes a sufficiently well-defined problems that you can optimize against and the machine will do better than people," he says. "If it's fluid and changing and contextual, it's much harder to say what it means to do well."*

The complexity of crime scenes is not amenable to rote or highly structured approaches that a machine algorithm typically provides. Although identification of an illicit drug can be performed using these instruments as they present themselves as relatively simple and straight-forward analysis, the focus here is on crime scene investigation and reconstruction based on the recognition of relevant traces at the scene. The last line in the computer scientist's quote above exemplifies the situation presented in most complex crime scenes in that no two are ever exactly alike. This is one compelling reason for the need for experienced generalist scientists at the scene [20].

With field deployable instruments possessing analytical laboratory capabilities, a lay-person may conclude that there would be no need for benchtop instrumentation and laboratory scientists. This is an extremely naïve and dangerous conclusion to draw. People may confuse the ease-of-use of these instruments with a misleading perception of analytical sophistication, giving the user a false sense of scientific prowess. Further, this would encourage more of a black-box mentality and approach where a sample goes in one end a result comes out the other. Simply obtaining analytical results in the field does not accurately address the problem in the context of the overall investigation. In the hands of a non-scientist, there is an increased risk in compromising, contaminating, or even destroying the evidence when sampling for use with portable instruments. There is more to evidence analysis than obtaining data. This is not a new or hypothetical problem, as destruction of evidence at a scene by non-scientist investigators is disappointedly a recurring issue. For example, when discovering a bullet hole in a wall, too often overly enthusiastic non-scientist investigators cut holes in the walls to recover a bullet before adequately documenting the relevant details and determining the trajectory. Problem definition and informed sampling need to precede efforts at obtaining analytical results. Informed specimen selection is critical and requires the knowledge and approach of a scientist. Field deployable instruments are just **tools**. Having these field capabilities can be useful, but cannot supplant the need for scientific problem solving at the crime scene. The forensic scientist is required for both the front-end recognition, scientific hypothesis development and its rigorous testing, as well as back-end interpretation of the evidence. In the hands of a scientist, field-deployable instruments may be useful, but we cannot not lose sight of the fact that there is a complex judgement call than needs to be made by a knowledgeable generalist scientist. Maximizing the extraction of information from physical traces at the scene necessitates a need for judicious decisions concerning the relative benefit of its *in-situ* analysis or preservation for later analysis in the laboratory.

5. Conclusion

Serious problems have been delineated. These have persisted in the field of forensic science, and unfortunately have been given too little attention. Lamentably, some believe that there is little chance to reinstate criminalistics to its full potential. Worse yet, there are newly minted scientists who are not even aware of the legacy of criminalistics by virtue of incomplete educations and lack of relevant mentoring in favor of over-specialization. We are hopeful that this can be changed.

How do we go about remediating the problems we have discussed above? The authors' hope that this article will provide increased awareness of the existing problems and stimulate discussions of the importance of the generalist possessing appropriately broad-based scientific knowledge, and skills of thinking and reasoning.

The way to begin addressing these issues is the manner in which forensic scientists are educated in universities and trained in on-the job settings. Optimistically, there may be many undergraduate and graduate programs which meet this need, but in our experience there are those that do not. In this growing era of specialization and technology, it is unfortunate that too little attention is given to the fundamental philosophies and nature of criminalistics and the value of the generalist [8]. The physical evidence continuum spans three zones: the front-end of the crime scene and initial investigation, the middle laboratory, and the back-end interpretation. The primary areas of concern are in the front-end where the concepts of informed sample selection and rigorous scrutiny with the scientific method are unappreciated or are being ignored, and the back-end where the product of the various forms of scientific analysis are not being contextually interpreted. Ideally, these two issues would be best addressed by the inclusion of a generalist scientist and approach. This holistic philosophy and scientific approach is critical for both the education of the next generation of criminalists as well as the survival of the field of forensic science as an essential contributor to the justice system.

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