

HOW CAN FRANCIS BACON HELP FORENSIC SCIENCE? THE FOUR IDOLS OF HUMAN BIASES

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ABSTRACT: In this paper, I try to find ways to improve forensic science by identifying potential vulnerabilities. To this end, I use Francis Bacon's doctrine of idols, which distinguishes between different types of human biases that may prevent scientific and objective inquiry. Bacon's doctrine contains four sources for such biases: *idola tribus* (idols of the tribe), *idola specus* (idols of the den or cave), *idola fori* (idols of the market), and *idola theatri* (idols of the theatre). While his 400-year-old doctrine does not, of course, perfectly match up with our current world view, it still provides a productive framework for examining and cataloguing some of the potential weaknesses and limitations in our current approach to forensic science.

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Whether forensic science is actually a “science” has been extensively debated in the academic, professional, and general public media. Often the discussion is governed by well-entrenched adversaries who are concerned and motivated by interest about the outcome and implications of the debate. The difficulties are compounded by metatheoretical issues about what constitutes a science and the fact that not all sciences are equal and meet well defined and strict criteria. Furthermore, it is important to emphasize that forensic science is not a unitary field; it encompasses a whole spectrum of disciplines, some of which are more scientifically based than others. Clearly DNA analysis is more scientific than bite-mark and ear-print analysis.

With such inherent difficulties and motivational biases (to name just a few), I avoid entering the debate that lacks for the most part any meaningful impact. I, however, have often wondered if and how a constructive discussion can help identify those elements in forensics that are scientific (if any) and those elements that are less, or not altogether, scientific (if any). These could be very important to forensic science, as they guide the way and erect clear signposts of how to improve and become more scientific. In this paper, I try to contribute to forensic science by constructively discussing forensic science as

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a science. I do this by scrutinizing potential vulnerabilities and problems that exist within forensic science, in the hopes that by reflecting upon and examining these issues, I can highlight where improvement is needed. I will *not* be reaching any conclusions on whether forensic science is, or is not, a science. Some readers will no doubt be disappointed that I am not concluding that forensic science is not a science; whereas, others will feel dismay that I am not concluding that it is. But whatever value I offer to this debate, it will not be by reaching either conclusion, but rather by sidestepping it.

It is further important to note that the need for improvement by itself is by no means a sign of a lack of scientific rigor; on the contrary, a sign of any good science is its constant reflection, criticism, and examination. That is how sciences are formed and continue to develop and improve. The goal of my discussion is to raise questions and identify vulnerabilities that need attention, rather than to reach a metaconclusion on whether any particular forensic discipline can, at present, legitimately be called a “science.”

To provide a constructive framework for discussing some of these areas that may need improvement, I go back to the very foundations of modern sciences. These were laid out in part by Francis Bacon nearly 400 years ago in *Novum Organum*.¹ Certain ways of thinking and analysis preclude scientific investigations, whereas others form the basis on which science is both grounded and on which it is contingent. Francis Bacon developed the doctrine of “idols,” in which he laid out his understanding of the various obstacles that get in the way of truth and science—false idols that prevent us from making accurate observations and achieving understanding. These idols distort the truth, and thus stand in the way of science. He categorized these obstacles into four groups: (1) *idola tribus* (idols of the tribe), (2) *idola specus* (idols of the den or cave), (3) *idola fori* (idols of the market), and (4) *idola theatri* (idols of the theatre).²

Francis Bacon’s idols should not be confused with fallacies, hallucinations, or mere illusions. Nor should they be conceived in a religious sense as false gods. Rather, Bacon probably meant something closer to false ideas that prevent us from gaining access to the truth and achieving a more full and accurate understanding of nature. Acknowledging such idols and establishing safeguards against them are critical milestones of a science. This is achieved by finding ways to detect, recognize, and counter their effects. In this way,

1. LORD BACON, *NOVUM ORGANUM* (Joseph Devey ed., P. F. Collier & Son 1902) (1620) [hereinafter BACON, *NOVUM ORGANUM*]; Francis Bacon, *The New Organon; or, True Directions Concerning the Interpretation of Nature*, in 4 *THE WORKS OF FRANCIS BACON* 37 (James Spedding et al. eds., London, Longmans et al. 1875) [hereinafter Bacon, *True Directions*]. Lisa Jardine and Michael Silverthorne note that “Bacon’s *Novum Organum*, or *The New Organon*, takes its title from Aristotle’s work on logic, ‘Organon’ or ‘Instrument for Rational Thinking.’” FRANCIS BACON, *THE NEW ORGANON* xii (Lisa Jardine & Michael Silverthorne eds., 2000).

2. *E.g.*, FRANCIS BACON, *NOVUM ORGANUM* 4 (London, Thomas Lee 1676), *microformed on* Ann Arbor, Mich. Early English Books, 1641–1700, 1115:7 (Univ. Microfilms Int’l).

Francis Bacon's doctrine of idols helped lay down much of the foundation of modern science.³

Bacon's message was not of skepticism and inability to conduct objective inquiries; indeed, he believed that if people were "forewarned of the danger," they could "fortify themselves as far as may be against their assaults."⁴ Perhaps Bacon was naive in thinking that merely naming and describing these idols in itself might counter their powers. Nevertheless, this may well limit the idols' effects, and combined with more actions—such as best practices, correct reliance on technology, training, and other related measures—a much more scientific and objective endeavor is possible.

Each of Francis Bacon's idols encompasses a different source of potential error that may limit us from accessing the truth and achieving a scientific examination. Each idol produces specific vulnerabilities and a distinct set of counter measures to prevent or minimize its potential powers. For example, there are errors that can arise when the method itself falls prey to an idol, and there are errors that can arise from the application and execution of the method falling prey to an idol. Similarly, there are idols that are inherent to human cognition, and there are idols that arise from organizational culture and structure. In what follows, I will use Francis Bacon's doctrine of idols as a tool to help understand and examine some of the challenges and obstacles facing forensic science.⁵

I. IDOLA TRIBUS (IDOLS OF THE TRIBE)

For Bacon, obstacles derive from being members of our species, from the very fact of our being human. "The idols of the tribe are inherent in human nature and the very tribe or race of man; for man's sense is falsely asserted to be the standard of things . . ." ⁶ These idols reflect and derive from what is common to all of us, from our very nature. They result from our inability to look at the world from "outside" of ourselves, to see things as they actually are, instead of seeing them as distorted by our own mental processes. Bacon explained, "[a]nd the human understanding is like a false mirror, which, receiving rays irregularly, distorts and discolours the nature of things by min-

3. Bacon is one of a group of scientists from 1500–1700 whose work helped lay down much of the foundation of modern science, with *Novum Organum* Bacon's "best known and important work." WILBUR APPLEBAUM, *THE SCIENTIFIC REVOLUTION AND THE FOUNDATIONS OF MODERN SCIENCE* xv (2005).

4. Bacon, *True Directions*, *supra* note 1, at 53.

5. Since I am using Bacon's doctrine of idols as a tool, as a framework for discussing forensic science, I will abide by it only loosely, applying it flexibly and pragmatically to this discussion. Please note Houck's application of Bacon's idols in Max M. Houck, *Science and Management: Using Bacon's Four Idols as a Theory of Managing Knowledge Workers*, KIMBERLY-CLARK PROFESSIONAL, Mar. 6, 2007, http://www.imakenews.com/eletra/mod_print_view.cfm?this_id=800886&u=kcprofessional&issue_id=000177836&lid=b9tgvRQ&uid=b1jnLSF3. For a general classification of errors, see Scott A. Shappell & Douglas A. Wiegmann, *Applying Reason: The Human Factors Analysis and Classification System (HFACS)*, 1 HUM. FACTORS & AEROSPACE SAFETY 59 (2001).

6. BACON, *NOVUM ORGANUM*, *supra* note 1, at 20.

gling its own nature with it.”⁷ This is a profound recognition of one of the fundamental insights of modern cognitive psychology: that *the mind is not a camera*, that we see selectively, and our understanding is inevitably partial and distorted.⁸ Indeed, we might say that Bacon’s *idola tribus* are an inevitable consequence of the way that our brains process information and the architecture of cognition that defines our perception, judgments, and decision making.⁹

Our brain and cognitive processes enabled us to survive and thrive as a species over many millions of years. Our flexible capacity to make sense of huge amounts of information, to prioritize and chunk information together, to draw conclusions even in the face of ambiguous and missing information (to name just a few cognitive powers), has underpinned effective and intelligent human performance. These special abilities are particularly noticeable and remarkable with human expertise, such as latent fingerprint examiners.¹⁰

These cognitive and brain processes that give rise to intelligence and to expertise, however, also generate vulnerabilities.¹¹

Expertise is correctly, but one-sidedly, associated with special abilities and enhanced performance. The other side of expertise, however, is usually surreptitiously hidden. Along with expertise, performance is also degraded, culminating in a lack of flexibility and error. . . . brain functions and cognitive architecture involved in being an expert. . . . the very making of expertise, entail [information processing] computational tradeoffs that result in functional degradation [and error].¹²

Francis Bacon acknowledged these idols as standing in the way of scientific understanding and observations. The *idola tribus* are inherent to us and our making, and thus, they cannot be directly and totally eliminated. They reflect cognitive trade-offs built into our cognitive architecture and brain processes. Human intelligence, and in particular expertise, entails mental representations and cognitive processes that introduce selectivity and distortions of information, as well as a whole range of other cognitive side effects. Thus, superior abilities introduced through expertise—paradoxically—also introduce degradation in performance.¹³

These assets and these vulnerabilities are inherent to the cognitive architecture and constitute two inevitable sides of the same coin. As such, we cannot ever eliminate them completely without also eliminating much of our own

7. Bacon, *True Directions*, *supra* note 1, at 54.

8. Itiel E. Dror, *Perception Is Far from Perfection: The Role of the Brain and Mind in Constructing Realities*, 28 BEHAV. & BRAIN SCI. 763, 763 (2005).

9. See generally *id.*; Itiel E. Dror & Peter A.F. Fraser-Mackenzie, *Cognitive Biases in Human Perception, Judgment, and Decision Making: Bridging Theory and the Real World*, in CRIMINAL INVESTIGATIVE FAILURES 53 (D. Kim Rossmo ed., 2009).

10. See generally Thomas A. Busey & Itiel E. Dror, *Special Abilities and Vulnerabilities in Forensic Expertise*, in THE FINGERPRINT SOURCEBOOK 15-1 (forthcoming 2010) (this book is being published online in stages at <http://www.ojp.usdoj.gov/nij/pubs-sum/225320.htm>).

11. Itiel E. Dror, *Paradoxical Functional Degradation in Human Expertise*, in THE PARADOXICAL BRAIN (Narinder Kapur et al. eds., forthcoming 2011) (manuscript at 3, on file with author).

12. *Id.* (manuscript at 2, on file with author).

13. *Id.*

cognitive powers. What we must do instead is control and minimize them through proper training and the development of best practices and procedures that directly address these idols. Sequential unmasking, following the principle of “keep the processes of data collection and analysis as blind as possible for as long as possible,”¹⁴ is an example of a good way to avoid and safeguard, as much as possible, against some *idola tribus* (for example, in DNA analysis). In sequential unmasking, *idola tribus* (as well as other idols discussed in the paper) are minimized by temporarily keeping information from the forensic experts.¹⁵ Information is unmasked sequentially, and with each unmasking, analysis is conducted and documented.¹⁶ Only then does further unmasking take place.¹⁷

Cognitive technologies, such as the Automated Fingerprint Identification System (AFIS), can also help deal with idols, but only if the technology is correctly collaborating and distributing cognition between the human expert and the technology. “AFIS ought to change the way fingerprint experts conduct comparisons, and what they require in order to declare a ‘match,’ because making identifications is simply not the same cognitive task as it was prior to the use of massive, automated computerized databases.”¹⁸ Hence, the changes brought about with the increasing use of cognitive technologies may eliminate some idols, but they also may modify the way existing idols affect human performance, now causing them to play different roles when technology is involved, as well as introducing new idols that did not exist before.¹⁹

Within *idola tribus*, Francis Bacon recognized the human tendency to engage in what we would now refer to as *wishful thinking* and *confirmation bias*: what he characterized as a natural inclination to accept, believe, and even prove what we want to be true, and then rush to conclusions because we want them to be true. He warned of how emotions stand in the way of finding the truth, as well as cause selective attention to information and limit abilities to take in and objectively process all the information. The erroneous identification of the Madrid bomber²⁰ is an example of how *idola tribus* can indeed interfere with observation and analysis. In this case a number of latent fingerprint examiners incorrectly identified Brandon Mayfield as the Madrid

14. Robert Rosenthal, *How Often Are Our Numbers Wrong?*, 33 AM. PSYCHOLOGIST 1005, 1007 (1978).

15. See Dan E. Krane et al., *Letter to the Editor: Sequential Unmasking: A Means of Minimizing Observer Effects in Forensic DNA Interpretation*, 53 J. FORENSIC SCI. 1006, 1006 (2008).

16. *Id.*

17. *Id.*

18. Itiel E. Dror & Jennifer L. Mnookin, *The Use of Technology in Human Expert Domains: Challenges and Risks Arising from the Use of Automated Fingerprint Identification Systems in Forensic Science*, LAW, PROBABILITY & RISK (forthcoming 2010) (manuscript at 5, posted Jan. 22, 2010, as an Advance Access article on the Law, Probability & Risk Web site).

19. *See id.*

20. *See generally* Robert B. Stacey, *A Report on the Erroneous Fingerprint Individualization in the Madrid Train Bombing Case*, 54 J. FORENSIC IDENTIFICATION 706–18 (2004), available at http://www.fbi.gov/hq/lab/fsc/backissu/jan2005/special_report/2005_special_report.htm.

bomber.²¹ In an investigation that followed this error, the Office of the Inspector General concluded that confirmation bias was a contributing factor in the erroneous identification.²²

Research studies have well established that confirmation bias is widespread across a great variety of areas and domains.²³ Recent empirical experimentation specifically demonstrates that *idola tribus* can affect fingerprint analysis. When fingerprints were shown within an emotional context, they were more likely to be judged as a match than when the same fingerprints were presented within an emotionally neutral context.²⁴ These effects, however, were observed only when the fingerprints were ambiguous and the participants in this study were novices.²⁵ When the fingerprints were clearly a match or a nonmatch, the emotional context had no observable effect.²⁶ Other studies further demonstrate that not all emotional contexts, under any condition, affect decision outcome.²⁷

Indeed, even if the context affects and biases the decision making process, it does not necessarily mean that in each and every case the biasing knowledge will actually affect the decision outcome.²⁸ If the bias is in the direction of the correct decision, then the evidentiary data may bring the decision considerations past the decision threshold, and the bias will only push the accumulated considerations further in the same direction.²⁹ Even if the bias is in a contradictory direction from the evidentiary data, this does not necessarily mean that the bias will lead to an incorrect outcome.³⁰ It might be, for example, that the biasing information will affect the considerations of the decision maker to some extent, but not enough to affect the actual decision. The more ambiguous the data, however, the more likely a bias will affect the actual decision.³¹

Other research, this time with latent fingerprint examiners doing real casework, demonstrates that *idola tribus* are indeed an issue with forensic examination.³² This time, however, the pairs of prints were presented in different

21. *Id.*

22. OFFICE OF THE INSPECTOR GEN., U.S. DEP'T OF JUSTICE, A REVIEW OF THE FBI'S HANDLING OF THE BRANDON MAYFIELD CASE 144 (2006) [hereinafter OIG].

23. See generally Raymond S. Nickerson, *Confirmation Bias: A Ubiquitous Phenomenon in Many Guises*, 2 REV. GEN. PSYCHOL. 175 (1998).

24. Itiel E. Dror et al., *When Emotions Get the Better of Us: The Effect of Contextual Top-Down Processing on Matching Fingerprints*, 19 APPLIED COGNITIVE PSYCHOL. 799, 805 (2005).

25. *Id.* at 806.

26. *Id.* at 805.

27. See, e.g., Lisa J. Hall & Emma Player, *Will the Introduction of an Emotional Context Affect Fingerprint Analysis and Decision-Making?*, 181 FORENSIC SCI. INT'L 36 (2008).

28. See generally Itiel E. Dror, *Letter to the Editor: On Proper Research and Understanding of the Interplay Between Bias and Decision Outcomes*, 191 FORENSIC SCI. INT'L e17 (2009).

29. *Id.* at e17.

30. *Id.*

31. See generally Itiel Dror & Robert Rosenthal, *Meta-Analytically Quantifying the Reliability and Biasability of Forensic Experts*, 53 J. FORENSIC SCI. 900 (2008).

32. See, e.g., Itiel E. Dror & David Charlton, *Why Experts Make Errors*, 56 J. FORENSIC IDENTIFICATION 600 (2006); Itiel E. Dror et al., *Contextual Information Renders Experts Vulnerable to Making Erroneous Identifications*, 156 FORENSIC SCI. INT'L 74 (2005); Dror & Fraser-Mackenzie, *supra* note 9.

contexts to determine if context affects decision outcomes. Many examiners reached different conclusions when the same prints were presented within a different context.³³

To find the scientific truth, one must find a way to minimize errors that “arise either from the uniformity of the constitution of man’s spirit, or its prejudices, or its limited faculties or restless agitation, or from the interference of the passions, or the incompetence of the senses”³⁴ What forensic scientists need to realize is that these *idola tribus* are within all of us. Their presence does not mean that forensic practitioners are failing at their duties. Their presence does not even make forensic science unscientific. Rather, the presence of *idola tribus*—of the distortions, biases, and knowledge that affect what and how we see—is simply part of what it means to be human. And as Bacon suggested to us nearly four centuries ago, recognizing our limits and our cognitive imperfections is the first step towards addressing them effectively.

II. *IDOLA SPECUS* (IDOLS OF THE DEN OR CAVE)

The *idola specus* are not, according to Bacon, as inevitable and universal as the *idola tribus*.³⁵ Instead, these idols vary from one person to another and are a function of the individual’s experiences, education, training, and other personal traits. Rather than derived from human nature itself, as the *idola tribus* are, these idols are a function of nurture. Different people, based on their specific upbringing, life experiences and professional affiliations, have developed personal allegiances to groups, ideologies, disciplines, theories, or methodologies. As a result, a person may “corrupt[] the light of nature, either from his own peculiar and singular disposition, or from his education and intercourse with others, or from his reading, and the authority acquired by those whom he reverences and admires”³⁶ Plato’s cave provides much insight to this type of idol and the cultural difficulties in changing it.³⁷

Idola specus perhaps include issues of personal preference and motivation. Reasoning, perception, and decision criteria are all affected by motivation and preferences.³⁸ Scientific objectivity may then be compromised by such idols. It is only natural that examiners are motivated to find matches and solve

33. Four out of six examiners changed at least one decision in one study, Dror & Charlton, *supra* note 32, at 610, and four out of five in another study, Dror et al., *supra* note 32, at 76. For their overall analysis, collapsing the data from both studies to quantify the level of *idola tribus* bias, see Dror & Rosenthal, *supra* note 31.

34. BACON, *NOVUM ORGANUM*, *supra* note 1, at 28.

35. BACON, *NOVUM ORGANUM*, *supra* note 1, at 20–21; Bacon, *True Directions*, *supra* note 1, at 54.

36. BACON, *NOVUM ORGANUM*, *supra* note 1, at 21.

37. See generally PLATO, *Republic*, in *COMPLETE WORKS* 1132 (John M. Cooper ed., 1997).

38. See generally Emily Balcetis & David Dunning, *See What You Want to See: Motivational Influences on Visual Perception*, 91 *J. PERSONALITY & SOC. PSYCHOL.* 612 (2006); Peter H. Ditto & David F. Lopez, *Motivated Skepticism: Use of Differential Decision Criteria for Preferred and Nonpreferred Conclusions*, 63 *J. PERSONALITY & SOC. PSYCHOL.* 568 (1992); Ziva Kunda, *The Case for Motivated Reasoning*, 108 *PSYCHOL. BULL.* 480 (1990).

crimes.³⁹ Charlton et al. found that fingerprint examiners are indeed highly motivated to catch criminals, especially in high profile or serious cases.⁴⁰ While such motivation is not surprising, and indeed may be valuable, it also may lead to bias or overeagerness to find a “solution” (that is, cognitive closure).

Motivational bias is not a new phenomenon and has been well studied and documented in many areas.⁴¹ It has not been sufficiently studied, however, within the forensic science domain. Motivation has many forms and comes in a variety of disguises. For example, having a target to compare to may cause motivated perception that affects what an expert examiner may see in the actual evidence.⁴² An illustration of such effects in forensic science is when evidence of an image of the perpetrator car’s registration plate number is matched against a “target” registration number of a known suspect, causing potential bias in the perception of the evidence so that it fits the target.⁴³

The issues are not simple. Take for example the nature of ACE-V, the accepted and widely used procedure for latent fingerprint examination (friction ridge analysis), which is comprised of the following steps: Analysis, Comparison, Evaluation, and Verification.⁴⁴ The Scientific Working Group on Friction Ridge Analysis, Study and Technology (SWGFAST) indicates that ACE-V is *circular* in nature, stating specifically that this “[m]ethod of [f]riction [r]idge [e]xaminations” is a “*recurring* application of . . . (ACE-V).”⁴⁵ This means that after comparison and evaluation of the latent print in relation to the suspect “target” ten-print, examiners can go back to their initial analysis, reanalyze the evidence, and modify their initial perception of it.

This allows the comparison and evaluation to the target ten-print to influence the analysis of the actual evidence, and thereby opens the door to motivated perception and a whole set of cognitive biases and influences. An attempt at a solution to this problem may entail imposing a *linear* nature to ACE-V, whereby analysis of the latent prints is conducted independently of the comparison and evaluation, and a return to the analysis stage and reanalysis after exposure to the suspect target ten-print during the comparison and evaluation stages is not allowed.

39. David Charlton et al., *Emotional Experiences and Motivating Factors Associated with Fingerprint Analysis*, J. FORENSIC SCI. (forthcoming 2010).

40. *Id.*

41. See generally, e.g., Karl Ask & Pär Anders Granhag, *Motivational Bias in Criminal Investigators’ Judgments of Witness Reliability*, 37 J. APPLIED SOC. PSYCHOL. 561 (2007); Balcetis & Dunning, *supra* note 38.

42. Itiel Dror, *Biased Brains*, 116 POLICE REV. 20 (2008).

43. *Id.*

44. SCIENTIFIC WORKING GROUP ON FRICTION RIDGE ANALYSIS, STUDY AND TECH. (SWGFAST), FRICTION RIDGE EXAMINATION METHODOLOGY FOR LATENT PRINT EXAM’RS 2 (2002), http://www.swgfast.org/Friction_Ridge_Examination_Methodology_for_Latent_Print_Examiners_1.01.pdf.

45. SWGFAST establishes guidelines and standards for the forensic examination of fingerprints, palm prints, and foot prints. *Id.* (emphasis added).

The examination of a latent print against a suspect ten-print, however, may also allow examiners to notice certain bits of information by directing their attention to those areas that do require special attention and further processing. Hence, rejecting a circular nature to ACE-V fingerprint matching and imposing a linear procedure may be “throwing out the baby with the bath water.” The problems are complex, and there is no simple answer.

A solution may entail imposing an initial analysis of the latent print in isolation from the target, but also allow, with clear and detailed documentation, retroactive changes after comparison to the target ten-print. The solution not only must include documentation of such “reanalysis” influenced by the exposure to the target, but also may require distinguishing during the initial analysis those characteristics that are strong and cannot be changed after exposure to the target from weaker characteristics that are liable to modification. The implications and dangers of different procedures, such as acceptance of low quality latent prints that do not contain sufficient information for comparison (or, in contrast, rejecting latent prints that are low in quality but are still sufficient for comparison), need to be carefully considered. The discussion above is only an illustration that methods should be developed with caution so they do not fall prey to Bacon’s idols.

Idola specus go beyond motivation, as they include how individuals see themselves and with whom they identify. Research has yet to examine whether forensic examiners’ affiliation with police or their own perceived role in crime fighting, or both, may influence their observations and analysis. It is clear, however, that this is a point to which forensic science, as a science, must pay careful attention, taking precautions to ensure that such affiliations and allegiances have no (or as minimal as possible) effects on objective and scientific work within forensics. One solution is to separate forensic laboratories from law enforcement agencies.⁴⁶ Such a move may have positive results in terms of minimizing (or even eliminating) police influences.

There are three points to consider, however. First, what are the advantages (if any) of having forensic laboratories within law enforcement agencies? If there are any (and there clearly are some advantages), how important are they? And how do they weigh and balance against idola specus and risks from these affiliations? Second, might there be ways to keep forensic laboratories within law enforcement agencies but to take actions to counter the idola specus? What are these actions, and how effective can they be? Third, we must recognize that by removing the forensic laboratories from law enforcement agencies, they will not be void of context and affiliation. They must be located somewhere, and in any environment there inevitably will be context, affiliation, and allegiances. Might new or different settings raise new concerns? It

46. Paul C. Giannelli, *The Abuse of Scientific Evidence in Criminal Cases: The Need for Independent Crime Laboratories*, 4 VA. J. SOC. POL’Y & L. 439, 478 (1997); Paul C. Giannelli, *Wrongful Convictions and Forensic Science: The Need to Regulate Crime Labs*, 86 N.C. L. REV. 163, 227–28 (2007); COMM. ON IDENTIFYING THE NEEDS OF THE FORENSIC SCI. CMTY. ET AL., NAT’L RESEARCH COUNCIL OF THE NAT’L ACADS., *STRENGTHENING FORENSIC SCIENCE IN THE UNITED STATES: A PATH FORWARD* 190–91 (2009) [hereinafter NRC REPORT].

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could be that moving forensic laboratories out of one context, by itself, may solve one problem, but bring about another problem. The point here is not to resolve this complex and difficult question, but rather to frame it as an example of *idola specus*, one deserving serious and considered attention. These questions of affiliation and the potential biases that they create also relate to communications and interconnections between people, the subject of our next set of Baconian idols, *idola fori*.

III. *IDOLA FORI* (IDOLS OF THE MARKET)

By the very “intercourse and association of men with each other,” distortions of the truth arise.⁴⁷ What others think, and our interactions and communications with fellow examiners and detectives, may affect our ability to do a proper scientific observation and inquiry. One of the issues that has received little scientific research and examination is the verification process, one stage in the ACE-V method.⁴⁸ The idea behind verification is that by having a second (or even third) examiner do his or her own analysis, we can have increased confidence in the conclusions reached by latent fingerprint examiners. But there has been quite a debate on how verification needs to take place. Interestingly, known erroneous identifications, such as Mayfield⁴⁹ and Cowans,⁵⁰ were not detected during the verification stage (nor by the defense experts).

Verification is clearly important and needed. However, what it entails and when to apply it is less clear. For example, is one verification sufficient or are two verifications needed? Should all conclusions be verified or only matches? Is blind verification essential? And what does “blind” verification mean (blind to the decision itself, to the reasons why it was reached, to who made the initial decision, to the fact that there was already an initial decision, and so forth)? What is clear is that verification is important, and that there are many ways to implement it. There seem, however, to be very few, if any at all, scientific experimental studies that have systematically examined, evaluated, and compared the different ways of doing verifications or that have determined whether the verifier knowing that he or she is “verifying” makes a difference. Such studies and experimentally based procedures for assessing verification are essential for countering *idola fori* and for establishing forensics as a science.

Understanding how “knowledge” matters, and what should or should not be communicated in order to minimize bias and other cognitive effects, will undoubtedly improve the field. For example, verifiers rarely find errors; there-

47. Bacon, *True Directions*, *supra* note 1, at 54.

48. *See supra* note 44 and accompanying text.

49. *See supra* notes 20–22 and accompanying text.

50. Cowans’ conviction for shooting a police officer in Massachusetts was based largely on an erroneous fingerprint identification. In February 2004, after serving 6.5 years (of a 30–45 year sentence), the conviction was overturned. *See* Jonathan Saltzman & Mac Daniel, *Man Freed in 1997 Shooting of Officer: Judge Gives Ruling After Fingerprint Revelation*, BOSTON GLOBE, Jan. 24, 2004, at A1. *See also* ANTHONY J. BERTINO, FORENSIC SCIENCE: FUNDAMENTALS AND INVESTIGATIONS 144 (2008).

fore, naturally, it is hard to keep motivation high, and there is a cognitive bias to verify. I suggest that a simple way to improve the quality of verification is to intentionally include, occasionally, a similar *nonmatch* pair of prints in the verification processes. Similar solutions already have been implemented in airport security where x-ray operators examine bags.⁵¹ Such measures in forensic science are relatively easy to implement, cost very little, and allow improved processes as well as quality control.

Scientific studies will provide insights that will enable greater efficiency in forensic work from a practical perspective. For example, I have suggested that the need for verification, and what sort of verification, may be highly dependent on the difficulty of the decision and the type and likelihood of a potential error. In cases with greater cognitive difficulty, when errors are more likely, more stringent verification procedures are needed; whereas more simple and straightforward prints may not require the same level and type of verification. Hence, studies on verification can not only provide understandings that will allow better forensic science to be more of a science, but they will enable forensic scientists to work wisely, using this knowledge to develop more appropriate and efficient—as well as cost effective—verification procedures.

But *idola fori* focuses mainly on language.⁵² Language has profound effects on how we think and perceive information, and even how we see things.⁵³ Furthermore, the terminology, vocabulary and jargon we use can generate mistakes because we use it without attention, without proper focus on its true meaning, and without measurable criteria, definition, and quantification. Take, for example, firearms identification. Language is clearly a potential problem when an examiner declares a match between two visual patterns because of sufficient “similarity,” when similarity is an unspecified quantum based on the examiner’s own experience.⁵⁴ The terms *similar* and *match* are inherently vague. If the examiners were to look for *identical* patterns, then the issue would be much easier. What we would need to agree on is the level of granularity and resolution to declare two things “identical,” as two things are never exactly the same at some level of granularity.

In firearms, as well as in other forensic domains, the patterns instead are judged by “similarity”—a similarity that enables one to conclude that the two patterns are so similar that one can accurately conclude that they originate

51. Threat Image Projection (TIP) software occasionally adds threat items, such as knives and guns, to routine X-ray images of ordinary bags so as to ensure that the x-ray examiners are alert and paying attention. See generally Adrian Schwaninger, *Threat Image Projection: Enhancing Performance?*, AVIATION SEC. INT’L, Dec. 2006, at 36; Transportation Security Administration (TSA), Threat Image Projection, <http://www.tsa.gov/approach/tech/tip.shtm> (last visited Feb. 2, 2010).

52. BACON, NOVUM ORGANUM, *supra* note 1, at 21.

53. See generally Marcelo Dascal, *Language as a Cognitive Technology*, in COGNITION AND TECH.: CO-EXISTENCE, CONVERGENCE, AND CO-EVOLUTION 37 (Barbara Gorayska & Jacob L. Mey eds., 2004).

54. Christophe Champod, *Fingerprint Examination: Towards More Transparency*, 7 LAW PROBABILITY & RISK 111, 111 (2008); Jennifer L. Mnookin, *The Validity of Latent Fingerprint Identification: Confessions of a Fingerprinting Moderate*, 7 LAW, PROBABILITY & RISK 127, 129 (2008).

from the same source.⁵⁵ The vagueness of the term similarity, though, raises the questions of what level of similarity is required, and how similar do the two impressions need to be. Forensic science may well fall prey to the traps of *idola fori* when examiners use language without attention, without proper focus on meaning, and without measurable criteria, definition, and quantification for critical terms that stand at the crux of their conclusions, such as “similarity” or “consistent with.”

The Association of Firearm and Tool Mark Examiners (AFTE) Theory of Identification was formalized in 1985 and published in the AFTE Journal.⁵⁶ This theory specifies the basis for comparing and identifying firearms and toolmarks. It states that “[t]he theory of identification as it pertains to the comparison of toolmarks enables opinions of common origin to be made when the unique surface contours of two toolmarks are in ‘sufficient agreement.’”⁵⁷ And it further states that “[c]urrently the interpretation of individualization/identification is subjective in nature, founded on scientific principles and based on the examiner’s training and experience.”⁵⁸ The potential problem here is the nonscientific nature of the identification criteria. If the comparison of toolmarks enables conclusions about common origin when the unique surface contours of two toolmarks are in “sufficient agreement,” what is the scientific definition and measurement of what constitutes such “sufficient agreement”? It seems that it is more in the eye of the beholder than strict scientific measures because it is determined without specific quantification and criteria. This subjective identification criterion has been criticized as unscientific and characterized as a central pitfall.⁵⁹

The subjective and unspecified identification criterion of *sufficient agreement* is an example of *idola fori*. Furthermore, the AFTE Theory of Identification stipulation that the determination of “sufficient agreement is the product of the examiner’s personal training, skills, and experience”⁶⁰ also involves

55. Ass’n of Firearm and Tool Mark Exam’rs (AFTE), *Theory of Identification, Range of Striae Comparison Reports and Modified Glossary Definitions—An AFTE Criteria for Identification Committee Report*, 24 AFTE J. 336 (1992).

56. *Id.*; The AFTE Theory of Identification was also published by the Scientific Working Group for Firearms and Toolmarks (SWGUN). Scientific Working Group for Firearms and Toolmarks (SWGUN), Admissibility Resource Kit: Review of Admissibility Elements, <http://www.swgun.org/> (follow the Admissibility Resource Kit hyperlink) (last visited Jan. 29, 2010).

57. AFTE, *supra* note 55, at 337.

58. *Id.* See details about the identification criteria in Ronald G. Nichols, *Firearm and Toolmark Identification Criteria: A Review of the Literature*, 42 J. FORENSIC SCI. 466 (1997) and in Jerry Miller & Michael Neel, *Criteria for Identification of Toolmarks Part III* Supporting the Conclusion*, 36 AFTE J. 7 (2004).

59. Adina Schwartz, *A Systemic Challenge to the Reliability and Admissibility of Firearms and Toolmark Identification*, 6 COLUM. SCI. & TECH. L. REV. 1, 14–15 (2005); Adina Schwartz, *Commentary on R.G. Nichols, Defending the Scientific Foundations of the Firearms and Tool Mark Identification Discipline: Responding to Recent Challenges*, 52 J. FORENSIC SCI. 1414, 1414–15 (2007).

60. Nat’l Inst. of Justice, *Firearm Examiner Training: Sufficient Agreement and Best Known Nonmatch*, http://www.ojp.usdoj.gov/nij/training/firearms-training/module09/fir_m09_t05_06.htm (last visited Dec. 30, 2009).

idola specus—the subjective individual’s experience determines decisions, rather than scientifically measurable criteria based on objective, quantifiable measurement divorced from and independent of the specific incidental individual who is making the observations. The vagueness of “sufficient similarity” is idola fori, and then the dangers of idola specus are introduced to fill in this vagueness. Without measurable, validated criteria, the dangers of confirmation bias and seeing what we expect to see are greater. The same issues and potential problems apply to other forensic domains, such as tire and shoe prints, bite and ear marks, handwriting, and even fingerprints.⁶¹

A striking example of how lack of definitions and standards can lead to bias in forensic science is in the perception and evaluation of bruises. The age of a bruise can be determined by its color, whereby the color *yellow*, for example, indicates that it is not recent.⁶² However, research shows that this classification system is based and dependent on what is regarded as “yellow” and that there is a lack of consistency in evaluating whether a bruise is yellow or not.⁶³

Even more striking is how this has introduced bias, rather than just entailing a relatively simple fix through standards and training. In response to the issues with determining if a bruise is yellow, a forensic physician stated in a published Letter to the Editor that “when asked the age of a bruise, I turn the question round, and ask how old it is thought to be,”⁶⁴ thus, adding potentially biasing contextual information rather than finding ways to agree what constitutes “yellow.” Furthermore, in the letter, the forensic physician finally adds, “I would suggest that adoption of these policies, would lead to less red faces in the witness box!”⁶⁵

In Baconian terms, the idola fori, those idols imposed on understanding by words, are of two kinds: (1) words for things that do not exist and (2) words that are misleading.⁶⁶ I have already discussed the vagueness of “yellow” and a very commonly used forensic term, “similarity.” How about “individualization”? This term is used by fingerprint examiners who may conclude “individualization” to exclude *all* others.⁶⁷ Is a more probabilistic language more robust? Would that help us resist idola fori and encourage precision that would make these fields more accurate and scientific?

61. Champod, *supra* note 54, at 111–12; Mnookin, *supra* note 54, at 137–39.

62. E.g., N.E.I. Langlois & G.A. Gresham, *The Ageing of Bruises: A Review and Study of the Colour Changes with Time*, 50 FORENSIC SCI. INT’L 227, 229–30 (1991).

63. L.A. Munang et al., *Lack of Agreement on Colour Description Between Clinicians Examining Childhood Bruising*, 9 J. CLINICAL FORENSIC MED. 171, 173 (2002); V.K. Hughes et al., *The Perception of Yellow in Bruises*, 11 J. CLINICAL FORENSIC MED. 257, 258 (2004).

64. Alan John Lyons, *Letter to the Editor: Regarding Lack of Agreement on Colour Description in Bruising*, 10 J. CLINICAL FORENSIC MED. 127, 127 (2003).

65. *Id.*

66. BACON, NOVUM ORGANUM, *supra* note 1, at 32; Bacon, *True Directions*, *supra* note 1, at 61.

67. Jeffery G. Barnes, *History*, in THE FINGERPRINT SOURCEBOOK 1-1, 1-15–1-17 (2009) (this book is being published online in stages at <http://www.ojp.usdoj.gov/nij/pubs-sum/225320.htm>); Michael J. Saks & Jonathan J. Koehler, *The Coming Paradigm Shift in Forensic Identification Science*, 309 SCIENCE 892, 892 (2005).

Language and *idola fori* relate also to how systems communicate and work. Thus, they also pertain to organizational structures and the flow of information within and between different entities. This relates to the way forensic work is carried out. For example, Larry S. Miller shows how different modes of conducting forensic examinations (in Miller's study, hair analysis) affect the accuracy of the conclusions reached by examiners (similar to issues with eyewitness lineup identification processes).⁶⁸ Koppl suggests that this is a main problem within forensics, and that combating and safeguarding against these *idola fori* should take place at an organizational level.⁶⁹ He emphasizes the importance of forensic science administration, thus increasing the objectivity of forensic science by reorganizing forensic work.⁷⁰ Koppl's argument is that some institutional structures are better for scientific inquiry than others.⁷¹ Because of the current way forensic analysis is carried out, a given laboratory often has a monopoly on the work. By introducing cross-laboratory examination of the same evidence, competition will increase incentives for error detection and prevention, thus creating a more scientific forensic discipline.⁷² The suggestions for a more scientific forensic discipline via administration are built on constructing new institutional epistemic designs.⁷³

IV. *IDOLA THEATRI* (OF THE "THEATRE")

Like *idola specus*, *idola theatri* are "made" and are not inherent to our make-up (unlike the *idola tribus*). These idols are divided into three kinds: *sophistical*, based on just a few anecdotal observations (or even no experimental empirical evidence); *empirical*, based on narrow research; and *superstitious*, based on unsupported or blind belief.⁷⁴ What is forensics based on? To what extent is it based on broad systematic scientific research? And to what extent is it based on narrow or even anecdotal in-house research and observations? As noted at the outset of the paper, forensic science is not a unitary field; it encompasses a whole spectrum of disciplines. It is beyond the scope of this paper to systematically examine each forensic discipline and to assess its basis. Furthermore, it is not the purpose of this paper to reach a conclusion about whether forensic science is scientific. So, I leave it open to what extent, if at all, each forensic discipline is *sophistical*, *empirical*, or *superstitious*, or is in

68. Larry S. Miller, *Procedural Bias in Forensic Science Examinations of Human Hair*, 11 LAW & HUM. BEHAV. 157, 160–61 (1987). For issues affecting eyewitness identification, see generally John Turtle et al., *Best Practice Recommendations for Eyewitness Evidence Procedures: New Ideas for the Oldest Way to Solve a Case*, 1 CAN. J. POLICE & SEC. SERVS. 5 (2003); Gary L. Wells & Elizabeth A. Olson, *Eyewitness Testimony*, 54 ANN. REV. PSYCHOL. 277 (2003).

69. Roger Koppl, *How to Improve Forensic Science*, 20 EUR. J. L. & ECON. 255, 264 (2005).
70. *Id.* at 275.

71. *Id.* at 255–57.

72. *Id.* at 267–74.

73. See generally Roger G. Koppl et al., *Epistemics for Forensics*, 5 EPISTEME 141 (2008).

74. Andrew James Harvey, *Immortal Signs: Science, Sacrament, and the Poetics of Immortality*, 26 LANGUAGE & COMM. 369, 373–74 (2006).

fact scientifically based. It is important, however, to discuss *idola theatri* to see if there are any issues surrounding the Superstitious idol.

This type of *idola theatri* distinguishes between what an examiner actually knows and what is merely believed. It is a well accepted principle in science that data undermine theory, not vice versa. How much, and to what extent (if at all), do forensic examiners accept their science without proper and sufficient questioning? How much of what they do is a matter of belief, a type of *idola theatri*, and how much of what they do is a matter of scientific knowledge? These questions are worth examination and can mark problem areas that need to be addressed for the purpose of increasing the science in forensic science. We must minimize, if not avoid all together, “idols which have crept into men’s minds from the various dogmas of peculiar systems . . . creating fictitious and theatrical worlds.”⁷⁵

Up to this stage, the *idola tribus*, *fori*, and *specus* all present obstacles that prevent us from true scientific observation and analysis. Any movement forward for improving forensic science, however, also has to overcome those well- and deep-rooted cultural issues that relate to belief—those that result from what Bacon called “fictitious” realities.⁷⁶ These are especially challenging, as no one likes his or her beliefs to be questioned, and any examination of beliefs often meets strong opposition and denial. As such, they are hard to discuss and can produce strong obstacles in the way of necessary improvements. If forensic examiners blindly believe in their ways, accepting forensic science without question or doubt, then these idols are especially hard to deal with. This form of resistance is, perhaps, part of human nature. No one likes to entertain the possibility of being wrong or having sent innocent people to incarceration. But defensiveness and lack of openness to discuss and examine potential idols in forensic science can be a serious obstacle that prevents forensic science from broadening and strengthening its scientific bases.

Let me illustrate the nature of some of these cultural issues. When it comes to human error, there is a whole literature of scientific studies spanning over 100 years. The literature clearly shows that the question is not whether humans make mistakes, but when and under what conditions they make them. In forensics, however, there has been significant resistance to admitting the possibility of error or to measuring its frequency or causes. There has been a strong belief that errors in forensic science are not a significant problem, but this belief has not been empirically tested in an adequate way. Examination, reflection, and criticism should be important and welcomed elements in forensic science. Identifying weaknesses and taking actions and countermeasures to avoid or at least to limit them must underpin any science, and forensic science is no exception. Weaknesses and human errors as discussed until now in Bacon’s idols were only minimally related to belief and culture. Bacon’s *idola theatri* have underpinned modern sciences by acknowledging these issues. Denying their very existence has been a problem in forensic science.

75. BACON, *NOVUM ORGANUM*, *supra* note 1, at 21–22.

76. *Id.* at 22.

Examples to illustrate such idols in forensic science are not rare. See, for instance, the published Letter to the Editor in the journal, *Police Review* (June 13, 2008), in response to an article about “Biased Brains.”⁷⁷ The formal response of the Chair of the International Fingerprint Society stated that any fingerprint examiner who is susceptible to bias is “an incompetent idiot.”⁷⁸ Or see another Letter to the Editor, this time to the professional journal of the Fingerprint Society, in which the chairman of the Fingerprint Society publicly states that any examiner that is susceptible to contextual bias or confirmation bias should not be a fingerprint examiner and needs to “seek employment in Disneyland.”⁷⁹ These hardly represent a culture of openness and examination aimed at finding weaknesses and improving the domain by providing proper safeguards and best practices. It is a response that reflects a belief in the pure objectivity of the forensic examination, and a response not based on scientific debate.

The point is that idola tribus are inevitable; they are part of what it means to be human. To declare that any examiner susceptible to them should not be in the field is to be beset by misunderstanding and superstition. The cultural issue of belief in forensic examination is well illustrated in another example. After the Madrid bomber erroneous identification,⁸⁰ one would expect, given that confirmation bias has been recognized as a contributing factor to the erroneous identification,⁸¹ that this and other cognitive biases will be a central part of a sourcebook in this area. Therefore, I submitted for this book a chapter dealing with these difficult issues.⁸² The chapter was reviewed, revised, and officially accepted for publication. Before publication, however, the editors removed it from the collection. Among other reasons, the editors justified their decision to exclude the chapter by stating they believed its inclusion in the sourcebook would damage the “widespread acceptance of the Sourcebook”⁸³ because fingerprint examiners would not be comfortable with what the evidence about confirmation bias shows.

These examples are just anecdotal illustrations of a defensive and closed attitude exhibited by some within the forensic science community. Accepting mistakes and errors as part of human nature and cognitive processes is an integral part of science. For example, in the fingerprint domain, examiners who make an error are subject to disciplinary actions and even dismissal. But errors

77. Martin Leadbetter, *Letter: Two Fingers to Research*, POLICE REV., June 13, 2008, at 20.

78. *Id.*

79. Martin Leadbetter, *Letter to the Editor*, 33 FINGERPRINT WHORLD 231, 231 (2007), <http://users.ecs.soton.ac.uk/id/FPW%20debate.pdf>.

80. See *supra* notes 20–22 and accompanying text.

81. OIG, *supra* note 22, at 144.

82. Itiel E. Dror, *Perceptual, Cognitive, and Psychological Elements Involved in Expert Identification* (2006) (unpublished, on file with author).

83. E-mail from Alan McRoberts, Editor, The Friction Ridge Sourcebook, to Dr. Itiel Dror, Senior Lecturer, University of Southampton (Apr. 12, 2007) (on file with author). At the end, only through the intervention of the National Institute of Justice (NIJ), which was funding the production of the book, the chapter was incorporated within another chapter of the Sourcebook (see Busey & Dror, *supra* note 10).

are part of life—they are to be acknowledged, managed, and minimized, not swept under the rug. These are exactly the idols that Francis Bacon discussed—those idols that in fact prevent science. Rather than welcoming and demanding research that attempts to scrutinize the field, some have resisted it through *ad hominem* personal attacks,⁸⁴ while others have engaged in-house research aimed at proving that the naked emperor is wearing clothes.⁸⁵ Research in-house in a system that culturally has a problem with acknowledging that errors do occur, and where belief in the current system is strong, often results in research that is too narrow and not derived from theoretical understanding and an adequate conceptual framework. Such research also may be self-interested, motivated to promote and validate existing procedures, and too close to the politics or ideology or persons at the work place, therefore suffering from many of Bacon's idols. It is difficult for forensic scientists to admit to error. Not only does *idola theatri* make this hard because error is contrary to much of their belief system, but also they rarely see and confront their errors.

In contrast to other domains, such as medicine, the military, and finance, where errors are “in your face” because of the death of a patient, friendly fire, or clear loss of funds, in the forensic domain, errors are rarely known. Cases like Mayfield⁸⁶ and Cowans⁸⁷ require very unusual circumstances, without which we may never know an error has even occurred. Furthermore, the errors discussed are not the kind of which examiners would be aware. On the contrary, these errors, and Bacon's idols, are ingrained and inherent to forensic examiners who are doing their job as dedicated, hard working, and well-intended experts.⁸⁸

The extensive National Research Council (NRC) inquiry into forensic science⁸⁹ has acknowledged “the findings of cognitive psychology on the potential for bias and error in human observers” and further stated that “[u]nfortunately, at least to date, there is no good evidence to indicate that the forensic science community has made a sufficient effort to address the bias issue.”⁹⁰ Moreover, the NRC committee found that “the extent to which practitioners in a particular forensic discipline rely on human interpretation that could be tainted by error, [or] the threat of bias . . . [is] significant.”⁹¹ It also recommended that

84. For example, one article printed in *Crime Lab Report* stated that “evidence of research and scholarly review” will not be found in “papers written by misguided academicians who have joined the chorus of forensic science critics hoping to bring attention to themselves and their universities.” *Forensic Pattern Identification: A History Lesson, and Some Advice, for Saks and Faigman*, CRIME LAB REPORT, Jan. 21, 2009, at 2, <http://www.crimelabreport.com/library/pdf/1-09.pdf>.

85. See, e.g., Hall & Player, *supra* note 27 and the rebuttal by Dror, *supra* note 28.

86. See *supra* notes 20–22 and accompanying text.

87. See *supra* text accompanying note 50.

88. Dror & Charlton, *supra* note 32, at 600–01.

89. NRC REPORT, *supra* note 46, at 1–4.

90. *Id.* at 8–9 n.8.

91. *Id.* at 87.

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[t]he National Institute of Forensic Science (NIFS) should encourage research programs on human observer bias and sources of human error in forensic examinations. Such programs might include studies to determine the effects of contextual bias in forensic practice (e.g., studies to determine whether and to what extent the results of forensic analyses are influenced by knowledge regarding the background of the suspect and the investigator's theory of the case).⁹²

Finally, the committee stated that

[i]n addition, research on sources of human error should be closely linked with research conducted to quantify and characterize the amount of error. Based on the results of these studies, and in consultation with its advisory board, NIFS should develop standard operating procedures (that will lay the foundation for model protocols) to minimize, to the greatest extent reasonably possible, potential bias and sources of human error in forensic practice.⁹³

Bacon's idols are, of course, not an exhaustive list of obstacles facing forensics in establishing and strengthening itself as a scientific discipline, but they do provide a useful framework for discussing some elements that need to be addressed in establishing and improving the scientific basis of forensic science. Some areas of forensics are more advanced than others, but like all scientific domains, there is always a place for constant examination, reflection, and improvements. For forensic science to advance and improve (which I hope we all accept as a shared goal), we must behave as scientists. "Scientists continually observe, test, and modify the body of knowledge. Rather than claiming absolute truth, science approaches truth either through breakthrough discoveries or incrementally, by testing theories repeatedly."⁹⁴ The discussions in this paper in no way attempt to declare that forensic science is lacking in scientific rigor, nor do they claim that forensics is scientifically based. The discussions aim to critically examine and question some elements in forensic science, to look for points of weakness, to identify potential problems that may need to be addressed, and to offer some recommendations for improvement.

92. *Id.* at 191.

93. *Id.*

94. *Id.* at 112.