Bridging the Science-Law Divide

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Abstract: Formal opportunities for members of the scientific and legal communities to engage in ongoing collegial consideration of issues at the interface of science and law are limited. In the late 1990s, the National Academies of Sciences, Engineering, and Medicine established the Committee on Science, Technology, and Law (CSTL) – composed of equal numbers of members from science, engineering, and law – to provide an ongoing forum that would build permanent links between these communities. The range of issues investigated by the CSTL and the influence of these explorations are discussed in this essay.

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Scientists and lawyers often appear to be speaking different languages. Each profession has its own culture and conventions, as well as its own jargon, and each employs distinctive means of resolving conflicts.[1] Often, when scientists and lawyers attempt to communicate, these differences can result in misunderstandings and confusion.[2] Moreover, when the institutions that represent these two professions attempt to collaborate, the likelihood of such difficulties can increase.

For almost two decades, the National Academies of Sciences, Engineering, and Medicine's Committee on Science, Technology, and Law (CSTL) has attempted to bridge the divide between the legal and scientific communities by developing projects and reports that encourage insightful consideration of scientific findings by legal institutions and appropriate oversight of the conduct of scientific, engineering, and biomedical research.[3] This essay discusses the origin of the CSTL and highlights some of the work the committee has undertaken to strengthen the bonds between science and law.[4]

The creation of a standing committee within the National Academies devoted to issues at the interface of science and law was not an easy decision. Many scientists within the National Academies viewed

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the sometimes brutal adversarial nature of the exchanges among legal professionals as unsuitable for an institution devoted to the scholarly search for scientific truth. The National Academies' mission of offering high-quality objective expert advice on some of the most pressing challenges facing the nation and the world seemed to some to be incompatible with the advocacy mission that animates much of legal discourse. When a need arose to address an issue pertinent to the legal profession, various committees of the National Academies would step up to offer advice on the particular situation, and then return to other issues focused more on scientific research than law.[5]

This ad hoc system of responding to issues involving questions of both science and law began to change in the 1990s. The science establishment could not help but recognize that science and law were becoming increasingly entangled in both the conduct of science and the development of public policy. Increasing regulation of scientific and academic research placed constraints on the conduct of scientific inquiry. Litigation was becoming more complex and often required testimony from scientific experts. Attorneys specializing in certain areas of litigation like toxic torts sometimes interpreted data, like clusters of adverse outcomes, in ways that were at odds with the consensus of the scientific community.

The legal system acknowledged the need for judges and attorneys to develop a more sophisticated understanding of science when, in the 1990s, the U.S. Supreme Court issued several decisions instructing judges to play a more active role in deciding what expert testimony a jury could hear. In the 1993 case *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, the Supreme Court stated that, in order to be admissible as evidence, scientific testimony must be based upon credible scientific methodology.[6] Judges were charged with conducting a rigorous assessment of the validity of scientific testimony before they decided to allow it. In establishing this standard, the Supreme Court quoted a brief submitted by the National Academy of Sciences and the American Association for the Advancement of Science as *amici curiae*: "Science is not an encyclopedic body of knowledge about the universe. Instead, it represents a *process* for proposing and refining theoretical explanations about the world that are subject to further testing and refinement."[7] The brief stated:

> The scientific community's well established criteria and institutional mechanisms for evaluating the validity of scientific assertions provide courts with clear and understandable guidance on how they can rationally and consistently evaluate scientific evidence. Courts should admit scientific evidence only if it conforms to scientific standards and is derived from methods that are generally accepted by the scientific community as valid and reliable. Such a test promotes sound judicial decision-making by providing workable means for screening and assessing the quality of scientific expert testimony in advance of trial.[8]

Several years later in 1999, in *Kumho Tire Co. v. Carmichael*, the Supreme Court considered whether "technical or other specialized knowledge," including testimony from the field of engineering, should also be evaluated for relevance and reliability in a manner consistent with the criteria offered in the *Daubert* decision. In that case, the National Academy of Engineering submitted an *amicus curiae* brief stating:

> Engineering, although differing in many respects from science, is founded on scientific understanding. In particular, the development of detailed understanding of the causes of the failure of an engineered device is a central feature of engineering: this effort involves a scientific-style investigation to understand the mechanism of failure at a fundamental, quantitative level.

In *Kumho*, the Supreme Court ruled that a trial court's gatekeeping role extends to all expert testimony.

In light of their important role in these Supreme Court decisions establishing the standards of admissibility for scientific evidence, the National Academies became more receptive to the establishment of an independent committee that could address topics that required an understanding of both science and law. The Academies' leadership came to agree with many leaders in the legal community (including U.S. Supreme Court Associate Justice Stephen Breyer and U.S. Federal District Court Judge Jack Weinstein) that there would be an ever-growing need for the legal and scientific communities to work with each other on issues of importance to the nation. The need for a prominent forum for representatives of these communities to get to know each other, understand their cultures, and exchange ideas was becoming more and more evident.

In March 2000, Donald Kennedy and Richard Merrill convened the Committee on Science, Technology, and Law, a new standing committee under the auspices of the National Academies of Sciences, Engineering, and Medicine.[9] Kennedy and Merrill sought to bring together distinguished members of the science and law communities to stimulate discussions that would lead to a better understanding of the role of science in legal decisions and government policies and to a better understanding of the legal and regulatory frameworks that govern the conduct of science. At biannual meetings, scientists and members of the legal community, including members of the legal academy and judiciary, were encouraged to bring to the committee topics of national importance that would be best addressed from the perspective of both communities. Sessions at each meeting were built around controversial or emerging issues and often led to the development of project ideas for consensus studies and convening activities. At the time it was established, Kennedy and Merrill noted, the CSTL could "not hope to canvass the entire terrain. Instead, we hope to become one of several contributors to the growing dialogue between science, engineering, and law; a supporter of initiatives by other organizations; and a catalyst for promoting productive collaboration among participants from all affected disciplines."[10] Eighteen years later, it's probably fair to say that Kennedy and Merrill could never have envisaged either the wide range of topics the CSTL would explore or the impact of these explorations.

In 2009, Kennedy and Merrill passed leadership of the CSTL to Richard Meserve and David Korn, and in 2015, Meserve and Korn passed leadership of the committee to David Baltimore and David S. Tatel (coauthors of this essay).[11] It is clear that the National Academies' and Kennedy and Merrill's decision to establish the CSTL was prescient. Many issues we face today, and will face in the future, require and benefit from the active engagement of both the legal and scientific communities.

The pursuit of truth is a goal of both science and law. Science is almost always open-ended: it is a process for investigating nature that reaches tentative interpretations based on the data at hand and subject to reinterpretation as continuing investigations generate ever more data that modify prior understandings or provide new insight. The law, too, requires constant refinement and reinterpretation. From both professions, society often demands that practical decisions be made on the basis of incomplete information. Both scientists and judges seek explanations for phenomena to gain a better understanding of a particular situation. The scientist seeks truth through an iterative process wherein a hypothesis is posed, data are collected and analyzed, and new understanding is gained that then gener-

ates new lines of inquiry. While this may appear to be a straightforward linear process, in practice, science is often surprisingly messy. Concurrent parallel lines of inquiry, collaborative exchange, and ongoing efforts to build a consensus through review and commentary on emerging research are the norm. The result in the best-case scenario is a transparent process that provides an opportunity for correction and refinement through peer review and further study. In science, evidence is continuously gathered, challenged, and refined until consensus develops, though a degree of uncertainty is associated with most scientific conclusions. The scientific community readily accepts that today's knowledge could be (and should be) revised if new data and findings lead to new conclusions. By continuing to collect evidence and test the limits of theories, the scientific enterprise, by its very nature, is self-correcting.

Law also builds on the past, though change proceeds at a more deliberate pace. In interpreting the law and in some admissibility decisions, precedent is given great weight, and judges typically do not have the option of postponing judgment until additional information emerges. In areas ranging from climate and the environment to medical practice and pharmacology, regulations and laws are written even though scientific understanding may be incomplete and uncertain. Legal disputes must be resolved without delay based upon the data at hand, and the legal community must respect legal conventions that may constrain the search for truth. As noted in *Ethyl Corporation v. Environmental Protection Agency*,

> We must look at the decision not as the chemist, biologist or statistician that we are qualified neither by training nor experience to be, but as a reviewing court exercising our narrowly defined duty of holding agencies to certain minimal standards of rationality. Although (our) inquiry into the facts is to be searching and careful, the ultimate standard of review is a narrow one. We must affirm unless the agency decision is arbitrary or capricious.[12]

While relying on legal precedent established by previous rulings may provide continuity, such precedent may impede consideration of advances in science and technology as they emerge outside the courtroom.

The difficulty in reforming common legal practice became apparent when, in 2006, under the CSTL's auspices, a committee was appointed to undertake a congressionally mandated study of the forensic sciences in the United States. The committee – which was cochaired by Judge Harry Edwards, U.S. Court of Appeals for the District of Columbia Circuit, and Constantine Gatsonis, professor and director of the Center for Statistical Sciences at Brown University – issued a landmark study in 2009 that found the forensic sciences to be systemically flawed. In reviewing the scientific underpinnings of many forensic disciplines, the committee found a lack of rigorous scientific research and noted that "[w]ith the exception of nuclear DNA analysis . . . no forensic method has been rigorously shown to have the capacity to consistently, and with a high degree of certainty, demonstrate a connection between evidence and a specific individual or source."[13] This finding undercuts decades of testimony by forensic experts who asserted that evidence associated with a crime scene could have originated with only one individual or object, to the exclusion of all other persons or objects in the world.[14]

For example, one of the forensic techniques that the committee reviewed in detail was forensic odontology, or "bite mark" analysis. Like many of the forensic sciences, the criteria for evaluating bite mark evidence were developed in the context of law enforcement investigations and not in scientific laboratories. In 1974, three dentists testified that they could match bite impres-

sions found on the body of an exhumed victim to a suspect, Walter Edgar Marx. Marx was convicted, and the decision was upheld by a California appeals court in 1975. Despite the unprecedented nature of the claims, the California appeals court declined to require a *Frye* hearing, since the techniques used by the dentists (for instance, X-rays, models, microscopy, and photography) were well established.[15] Since there was no scientific methodology or testing of bite marks, nor any science connecting an individual to bite marks, the court concluded there was therefore no need for such a hearing. Instead, the appeals court deferred to the trial judge who believed that bite mark evidence was sound. The Marx decision laid the foundation for the admission of bite marks into evidence and set a precedent that has influenced many courts, despite the fact that bite mark evidence has now largely been discredited.

In conducting its review, the committee found that

> Although the majority of forensic odontologists are satisfied that bite marks can demonstrate sufficient detail for positive identification, no scientific studies support this assessment, and no large population studies have been conducted. In numerous instances, experts diverge widely in their evaluations of the same bite mark evidence, which has led to questioning the value and scientific objectivity of such evidence.

Further, the committee noted that it "received no evidence of an existing scientific basis for identifying an individual to the exclusion of all others." Following such an assessment, one might expect that judges would no longer allow testimony that links a bite mark to a specific individual. Yet, today, bite mark evidence remains admissible in some courts,[16] although not in others.[17] The scientific community finds the resistance to change by the legal community difficult to understand. Scientists are mystified when the courts resist embracing new knowledge that represents a scientific consensus. It appears that the law has few systems designed to take advantage of the evolving nature of scientific knowledge. Judges seem to feel free to ignore scientific advances, especially in cases involving forensic sciences.[18] Procedures to aid scientific understanding in civil trials, such as *Daubert* hearings, appear to be far rarer in criminal trials, although the Court in *Daubert* was interpreting a federal rule of evidence that is in theory equally applicable in civil and criminal litigation. Research is needed to understand the extent to which *Daubert* hearings are held in civil and criminal cases. If there is a wide variation, it would be important to understand whether this is a failure of judicial education, or a reflection of a more systemic issue.[19]

Cases involving complex scientific evidence can place great demands on judges. Most judges do not come to the bench with a strong background in science or technology. Following the *Daubert* decision, judges needed more information on how scientists determine the validity of scientific assertions. In an effort to provide such assistance, the Federal Judicial Center (FJC), the research and education agency of the federal judiciary, developed a series of educational programs that allowed judges to interact with scientists to better understand the culture, process, and methods of science. In 1995, the FJC developed the first edition of the *Reference Manual on Scientific Evidence*, in part in response to the Supreme Court's *Daubert* decision. In order to satisfy *Daubert*'s reliability standards, the Supreme Court instructed judges to consider whether a proffered expert opinion was the product of scientific reasoning and scientifically sound methodology. The chapters in the *Reference Manual* describe basic principles of major scientific fields from which legal evidence is typically derived and provide examples of cases where such evidence was

used. The manual contains glossaries of technical terms that scientists may use in particular areas of scientific inquiry.

The purpose of the *Reference Manual* is to provide judges with sufficient understanding to hold an informed conversation with expert witnesses and attorneys while considering challenges to the admissibility of the scientific evidence. As noted in *Lead Industries Association, Inc. v. Environmental Protection Agency*:

> [T]he court "must understand enough about the problem confronting the agency to comprehend the meaning of the evidence relied upon and the evidence discarded; the questions addressed by the agency and those bypassed; the choices open to the agency and those made." . . . However, it is appropriate to sound some notes of caution about the limits of this exercise. First, we would be less than candid if we failed to acknowledge that we approach the task of examining some of the complex scientific issues presented in cases of this sort with some diffidence. More important, we stress that our review of the evidence is not designed to enable us to second-guess the Agency's expert decisionmaker. . . . Congress has entrusted the Agency with the responsibility for making these scientific and other judgments, and we must respect both Congress' decision and the Agency's ability to rely on the expertise that it develops.[20]

Soon after the establishment of the CSTL, the National Academies and the FJC recognized a unique opportunity to establish stronger ties between the scientific community and the federal judiciary. The director of the FJC and the program officer overseeing the Center's studies on scientific evidence were given permanent memberships on the committee. The FJC subsequently asked the CSTL to collaborate on the development of an expanded third edition of the *Reference Manual on Scientific Evidence*.

An advisory committee – cochaired by Judge Gladys Kessler, U.S. District Court for the District of Columbia, and Jerome Kassirer, professor of medicine at Tufts University, and including judges, scientists, engineers, and medical professionals – was charged with overseeing the development of reference guides on thirteen scientific, engineering, and medical topics. As in the previous editions, the guides were designed to assist judges as they attempted to assess the scientific foundation of scientific testimony and, in the absence of a jury, to adjudicate on differing interpretations of scientific evidence. In addition to updating previous guides, the expanded version included new chapters on topics such as neuroscience, forensics identification, exposure science, and mental health. The *Reference Manual* is provided to more than three thousand federal judges and is also widely used by state judges, attorneys, and law professors. The National Academies makes the *Reference Manual* available for free to the public, and it has become one of the forty most-downloaded reports of the over 9,900 reports issued by the National Academies, with 30 percent of the downloads coming from nations other than the United States. As Justice Breyer noted in the introduction to the volume, "This manual seeks to open legal institutional channels through which science – its learning, tools, and principles – may flow more easily and thereby better inform the law. The manual represents one part of a joint scientific-legal effort that will further the interests of truth and justice alike."[21]

Academic research in the United States is governed by a host of laws, regulations, and policies that provide oversight of scientists and engineers who conduct research using taxpayer dollars. The CSTL has evaluated numerous regulations and policies affecting scientific research and research institutions. In its early years, the CSTL became interested in government policies affecting access to, and the use and evalua-

tion of, research findings or scientific findings relied upon by government agencies. Questions arose as to the applicability of *Daubert* to administrative agencies.[22] This interest was stimulated by the Data Quality Act, which directed the White House Office of Management and Budget (OMB) to develop government-wide guidelines to "provide policy and procedural guidance to federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information . . . disseminated by Federal agencies."[23] Companion guidelines included in the OMB Information Quality Bulletin for Peer Review provided guidance to agencies regarding how to conduct peer review of the "most important science disseminated by the Federal Government."[24] Both the research community and federal agencies expressed concerns, however, that the proposed OMB guidelines would, in the name of quality and transparency, disrupt scientific practice and would be used by special interest groups to contest the scientific premises of government rules and regulations. To some, the Data Quality Act appeared to be a *Daubert*-like screening of scientific information and agency processes relied upon by federal regulatory agencies.[25] At the request of the OMB, in 2002 and 2003, the CSTL convened a series of workshops where the affected communities (federal agencies, researchers, public interest groups, and industry) could express their concerns to the OMB. John Graham, the administrator of the OMB's Office of Information and Regulatory Affairs (OIRA), and several other OMB senior staff attended these workshops. The exchange of information during these discussions led to substantive revisions to both sets of OMB guidelines and an apparently greater understanding of the scientific process by the OIRA.

Most recently, in 2016, the CSTL issued a report entitled *Optimizing the Nation's Investment in Academic Research: A New Regulatory Framework for the 21st Century*. The report was commissioned by Congress and authored by a CSTL study committee chaired by Larry Faulkner, president emeritus of the University of Texas at Austin; Harriet Rabb, general counsel of The Rockefeller University, served as vice chair. The report considers a broad range of regulations governing academic research, from proposal development to the acceptance of an award, to the conduct of research, to the final closeout of a contract or grant. The study recognizes the importance of regulation in protecting the government, research institutions, investigators, and the public from fraud, waste, and abuse, while providing an organizing framework for the conduct of research. The report found that the increasing number of laws, regulations, and policies emerging over past decades have had the unintended negative effect of diverting significant researcher time from research. In essence, the country is not reaping the full benefits from all the research it is funding:

> The continuing expansion of federal regulations and requirements is diminishing the effectiveness of the U.S. research enterprise and lowering the return on the federal investment in basic and applied research by diverting investigators' time and institutional resources away from research and toward administrative and compliance matters. A new framework . . . is needed to ensure that regulatory requirements are justified, proportional to the problems being addressed, and harmonized across funding agencies so as to create a more effective and efficient partnership between funding agencies and research institutions.[26]

Among its many recommendations, the report called for the establishment of a Research Policy Board as an "analytical, anticipatory, and coordinating forum on research regulatory policy." This recommendation, along with many of the committee's other recommendations, was enacted with the passage of several laws, including the 21st Century Cures Act (2016).[27]

The committee also called upon Congress to appoint a national commission on human research subjects and recommended that the Department of Health and Human Services withdraw its Notice of Proposed Rulemaking on the Federal Policy for the Protection of Human Subjects. The committee argued that since the 1978 issuance of the Belmont Report, which articulated three principles key to the protection of human beings used in research studies,

> the biomedical and sociobehavioral research enterprises have grown enormously. This growth, accompanied by the development of a remarkable number of new research capabilities and contexts, raises questions as to the optimum application and balancing of the Belmont principles, as well as whether these principles are, in and of themselves, still sufficient pillars upon which to build human research protection programs and regulations. In addition, the overarching legal and regulatory frameworks and institutional arrangements governing human research subjects require reconsideration and clarification.[28]

While a commission has not been appointed and the final rule was issued in January 2017, it is important to note that newly issued federal policy reflects many of the committee's concerns.[29] Most notably, it did not adopt a controversial proposal to require researchers to obtain informed consent to use unidentified biospecimens in research.

CSTL activities demonstrate the importance and value of having the legal and scientific communities involved in the development of the legal and regulatory apparatuses that govern research and in discussions about how scientific research is conducted. A better understanding of both cultures affords the nation an opportunity to maximize the value of its considerable investment in research for the benefit of the American economy and the health and social well-being of its citizens.

Regulation of emerging technologies has been of particular interest to CSTL members. The committee has convened meetings on synthetic biology, gain of function research, neuroscience, and human genome editing, to name just a few topics. In the course of these explorations, it has become increasingly clear that law and science speak only to some of the issues that arise, and that it is imperative to consider ethical frameworks as well. As emerging technologies become a more prominent part of public discussions, ethical, moral, and societal issues must be part of future public dialogues.

We have also learned that it is necessary to expand our discussions beyond just the United States to include colleagues from around the world. At the behest of the National Academy of Sciences (NAS) and National Academy of Medicine (NAM), the CSTL led the Academies' collaboration with the Royal Society and Chinese Academy of Sciences to organize an international summit on human genome editing.[30] A new gene editing tool, CRISPR-Cas9, captured the public's attention in 2015 when it became known that this tool could be used to alter the human germline. The use of CRISPR-Cas9 to edit human genes raises profound questions about the manner in which the DNA of living beings may be altered, as well as the genomes of future offspring. The two-and-a-half day summit, held in December 2015, received worldwide attention, with representatives from more than twenty countries in attendance. The live webcast attracted more than three thousand viewers from seventy-one nations. At the conclusion of the summit, the summit planning committee released a statement, "On Human Gene Editing":

> It would be irresponsible to proceed with any clinical use of germline editing unless and until (i) the relevant safety and efficacy issues have been resolved, based on appropriate understanding and balancing of risks, poten-

tial benefits, and alternatives, and (ii) there is broad societal consensus about the appropriateness of the proposed application. Moreover, any clinical use should proceed only under appropriate regulatory oversight.[31]

Recognizing that the human genome is "shared among all nations," the statement called for "an ongoing international forum to discuss potential clinical uses of gene editing; help inform decisions by national policymakers and others; formulate recommendations and guidelines; and promote coordination among nations."[32] Since the 2015 summit, the NAS and NAM issued a consensus report, *Human Genome Editing*, that indicated that, in the future, clinical trials for genome editing of the human germline could be permitted, but only for serious conditions under stringent oversight. The report outlines several criteria that should be met before allowing such trials to go forward.[33] Other organizations have issued guidance as well.[34] A second international summit co-organized by the NAS, NAM, the Royal Society, and the Academy of Sciences of Hong Kong will be held in Hong Kong in November 2018.[35]

As the CSTL continues to chart its course, it has identified several important topics where science, law, ethics, and international engagement will play a critical role.

In recent decades, major advances in neuroscience, psychology, behavioral economics, and related fields have expanded our understanding of human cognition and mental processes. This work has had wide-ranging significance in illuminating phenomena such as visual perception, memory, rational choice, and decision-making. A 2014 CSTL report, *Identifying the Culprit: Assessing Eyewitness Identification*, chaired by Thomas D. Albright, director of the Vision Center and Laboratory at the Salk Institute for Biological Studies, and Judge Jed Rakoff, U.S. District Court for the Southern District of New York, synthesized and applied insights from this body of research to the topic of eyewitness identifications. The report discussed the scientific foundations of visual perceptual experience and memory, identified key factors that can lead to error, and offered recommendations for best practices to improve the accuracy of eyewitness identification in criminal investigations. In 2017, the U.S. Department of Justice issued new procedures for how the FBI and other law enforcement agencies should ask eyewitnesses to identify suspects using photo lineups.[36]

The related topic of unconscious bias has garnered much attention in light of well-publicized incidents of police use of force against minority citizens. While this is hardly the first time the issue has been at the forefront of national conversation, today we can engage in this conversation against a backdrop of over two decades of scientific research on the cognitive mechanisms that underlie unconscious bias. The CSTL envisions a study that recognizes the pervasiveness of unconscious bias as a common aspect of mental processing in a wide variety of contexts affecting a wide variety of groups. For example, recent studies by social psychologist Kelly M. Hoffman and colleagues have demonstrated that medical students and residents who held false beliefs regarding biological differences between blacks and whites (for example, that black people's skin is thicker than white people's skin) showed racial bias in the accuracy of not only their pain assessments, but also their treatment recommendations.[37] In a separate context, then–acting director of the U.S. Office of Personnel Management, in congressional testimony offered in 2016, described gender bias in federal hiring practices and identified unconscious bias as the most challenging barrier to diversity and inclusion.[38]

At a recent speech to incoming students at Georgetown Law, Associate Supreme

Court Justice Ruth Bader Ginsberg observed that, while many overt barriers to employment discrimination are gone, what remains is unconscious bias, which is harder to address. Unconscious biases have profound implications for efforts to increase diversity in hiring and promotion practices across all sectors of the economy, for criminal justice, and for decisions regarding housing and finance.

Scientific understanding of unconscious bias has advanced considerably in recent decades, but this body of research has had minimal impact on law and policy.[39] Some courts and judges have occasionally recognized the reality of unconscious bias. As Justice Kennedy noted: "Recognition of disparate-impact liability under the [Fair Housing Act] also plays a role in uncovering discriminatory intent: It permits plaintiffs to counteract unconscious prejudices and disguised animus that escape easy classification as disparate treatment."[40] Nonetheless, there is no systematic or well-developed approach to how such biases should be taken into account under relevant legal standards.

The emerging body of research on unconscious bias has the potential to inform and motivate institutional reform in multiple environments. In police departments, universities, industry, and other settings, administrators are searching for ways to reduce unconscious bias not only to lessen legal exposure, but also to achieve diversity-related objectives and to improve organizational performance and credibility. By bringing the disciplined focus of science to bear on this critical issue, the CSTL seeks to stimulate new conversations about the nature of discrimination and to identify ways to counteract ingrained unconscious modes of information processing.

To take another example, the exploration of outer space has until recently been the exclusive domain of a few prominent governments. Today, however, we are witnessing increasing interest in the exploration of space by emerging nations and nongovernmental entities. Scientific and technological advances – such as the development of small satellites for research, communications, and remote sensing, and commercial launch services – are rapidly changing access to space and expanding the scope of space activities. The diversification and growth of new actors and activities in space raise questions about the adequacy of existing laws, regulations, and policies. As recently noted by Joan Johnson-Freese,

> Fifty years on, the Outer Space Treaty and its spin-offs are still appropriate. But interpretations of its provisions are, more than ever, being influenced by commercial interests and politics. Supplementary rules and norms are needed. In an era in which international cooperation on treaties is tenuous, informal agreements and resolutions must guide space-faring actors, protect the environment and prevent wars.[41]

The CSTL sees this new era of activity in space as an appropriate time to explore and evaluate the adequacy of the legal, policy, and regulatory regimes governing the exploration and use of space.

In this essay, we have taken the opportunity to describe the history of the CSTL, to provide some examples of the work the committee has done, and to identify areas of concern that will be the topics of study in the future. We have tried to illustrate the richness that emerges from thinking about the interface of science, technology, and law. Interestingly, both science and law have the same property of never being fixed and complete. It is our hope that having members from the worlds of science and law meet regularly provides a venue in which viewpoints are broadened on a range of issues, thus furthering understanding in both communities that extends beyond individual committee members.

As the knowledge of science and the procedures of law evolve, the need for this "cross-pollination" becomes ever more necessary. Thus, the work of the CSTL will never be complete, and its particular concerns will inevitably vary over time.

AUTHOR BIOGRAPHIES

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ENDNOTES

[1] "[L]aw and science are both knowledge-generating institutions, but . . . fact-making serves different functions in these two settings." Sheila Jasanoff, "Law's Knowledge: Science for Justice in Legal Settings," *American Journal of Public Health* 95 (S1) (2005): S49 – 59.

[2] As Susan Haack put it: "two simple observations: that the work of a scientist is very different from the work of an attorney or a judge; and that, when scientists give expert testimony or advise a court, a regulative body, etc., communication can be difficult and very imperfect." Susan Haack, "Scientific Inference vs. Legal Reasoning? – Not so Fast!" paper shared at the *Dædalus* authors' conference on "Science and the Legal System," July 2017, Cambridge, Massachusetts.

[3] The CSTL is not the first attempt at building better understanding and communication between these two communities. Indeed, Sheila Jasanoff was, and remains, a pioneer in this field, providing foundational understanding of the interactions between law and science. Also, in 1974, the American Association for the Advancement of Science and American Bar Association founded the National Conference of Lawyers and Scientists. See American Association for the Advancement of Science, "National Conference of Lawyers and Scientists," https://www.aaas.org/page/national-conference-lawyers-and-scientists. And, in 1975, the National Research Council established the Committee on Law and Justice "to improve governmental decision making and public policy, and promote the understanding and dissemination of research in matters involving law and justice." See The National Academies of Science, Engineering, and Medicine, http://sites.nationalacademies.org/DBASSE/CLAJ/DBASSE_073357.

[4] Throughout this essay, when we refer to the scientific and legal communities, we mean to include with the scientific community the engineering and medical communities, and when we refer to the legal community, we are including the judiciary, legal academy, legal practitioners, and policy-makers. (For a complete view of the CSTL's work, see www.nationalacademies.org/stl.)

[5] See, for example, the National Academies' reports: National Research Council, *DNA Technology in Forensic Sciences* (Washington, D.C.: National Academies Press, 2004); and National Re-

search Council, *Forensic Analysis: Weighing Bullet Lead Evidence* (Washington, D.C.: National Academies Press, 2004).

[6] *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993). In *Daubert*, the Supreme Court ruled that a "trial judge must ensure that any and all scientific testimony or evidence admitted is not only relevant, but reliable." To assist in this assessment, the Court offered some guideposts for identifying proffered scientific testimony that was properly grounded in scientific knowledge. The Court suggested that trial judges ought to consider: 1) whether a theory or technique "can be (and has been) tested"; 2) whether the theory or technique "has been subjected to peer review and publication"; 3) "the known or potential rate of error" of a particular scientific technique; 4) "the existence and maintenance of standards controlling the technique's operation"; and 5) a scientific technique's degree of acceptance within a relevant scientific community. The Supreme Court further developed these standards in *General Electric Co. v. Joiner*, 522 U. S. 136 (1997); and *Kumho Tire Co. v. Carmichael*, 526 U.S. 137 (1999). It should be pointed out, however, that the Court was careful to make clear that meeting these suggested standards was neither necessary nor necessarily sufficient to justify the admission of scientific evidence. Nonetheless, lower courts have often acted as though they were.

[7] Brief for the American Association for the Advancement of Science and the National Academy of Sciences as *amici curia* in Support of Respondent in *Daubert v. Merrell Dow Pharmaceuticals Inc.*, January 19, 1993. Emphasis in original.

[8] Ibid., 27. The brief specified criteria such as the generation and testing of hypotheses, replication of results, the use of peer review, and acceptance by the scientific community.

[9] Donald Kennedy is president emeritus of Stanford University, administrator emeritus of the U.S. Food and Drug Administration, and emeritus editor-in-chief of *Science* magazine. Richard Merrill is formerly of counsel for Covington and Burling, general counsel for the U.S. Food and Drug Administration, and dean emeritus of the School of Law at the University of Virginia.

[10] Donald Kennedy and Richard A. Merrill, "Science and the Law," *Issues in Science and Technology* 16 (4) (2000): 49–51.

[11] Richard Meserve is senior of counsel for Covington and Burling and president emeritus of the Carnegie Institution for Science. It should also be noted that he coauthored *amici curia* briefs submitted on behalf of the National Academies in both *Daubert v. Merrell Dow Pharmaceuticals* and *Kumho Tire Co. v. Carmichael*. David Korn is professor of pathology at Massachusetts General Hospital and Harvard Medical School, and dean emeritus at the Stanford University Medical School.

[12] *Ethyl Corporation v. Environmental Protection Agency*, 541 F.2d 1, 36–37 (D.C. Cir. 1976).

[13] National Research Council, *Strengthening Forensic Science in the United States: A Path Forward* (Washington, D.C.: National Academies Press, 2009), 7.

[14] The report stimulated an ongoing national discussion on the need to improve forensic science; prompted the creation of a DOJ–NIST National Commission on Forensic Science and the establishment by NIST of a Forensic Science Center of Excellence; led the FBI to review thousands of cases where testimony regarding hair evidence was suspect; generated multiple proposals of federal legislation adopting the report's recommendations; has been cited in numerous court decisions, including decisions by the U.S. Supreme Court (see Antonin Scalia in *Melendez-Diaz v. Massachusetts*: "According to the CSTL forensic science report, '[t]he majority of [laboratories producing forensic evidence] are administered by law enforcement agencies, such as police departments, where the laboratory administrator reports to the head of the agency.' And '[b]ecause forensic scientists often are driven in their work by a need to answer a particular question related to the issues of a particular case, they sometimes face pressure to sacrifice appropriate methodology for the sake of expediency.' A forensic analyst responding to a request from a law enforcement official may feel pressure – or have an incentive – to alter the evidence in a manner favorable to the prosecution."); and has generated ongoing media and popular cultural coverage (see, for example, *Last Week Tonight with John Oliver*, October 1, 2017, https://www.youtube.com/watch?v=ScmJvmzDcGo). Nonetheless, progress is slow and efforts to thwart progress continue: in 2017, the DOJ, under the direc-

tive of Attorney General Jeff Sessions, decided not to renew the National Commission, opting instead to appoint a former prosecutor as the DOJ's forensic science advisor.

[15] In *Frye v. United States*, the U.S. Court of Appeals for the D.C. Circuit ruled that to be admitted into court, scientific evidence must have "gained general acceptance in the particular field in which it belongs." *People v. Marx*, 54 Cal. App. 3d 100 (2d Dist. 1975). For a more detailed discussion of *People v. Marx*, see David L. Faigman, Edward K. Cheng, Jennifer L. Mnookin, et al., *Modern Scientific Evidence: The Law and Science of Expert Testimony*, 2016 – 2017 ed. (Eagan, Minn.: Thomson Reuters, 2016), sec. 35:5.

[16] See, for example, Honorable Jolene Grubb Kopriva, March 8, 2017, Opinion and Order in *Commonwealth of Pennsylvania v. Paul Allen Ross*, in which Judge Kopriva, in refusing to exclude bite mark evidence, wrote, "Although the use of bite mark evidence is beginning to face challenges, it would be premature for this court to order that the methodology is no longer generally accepted in the relevant scientific community."

[17] In 2016, the Texas Forensic Science Commission recommended a moratorium on the use of bite mark evidence in future criminal prosecutions in Texas until the technique could be scientifically validated, and ordered a review of every conviction in Texas in which bite marks were used.

[18] See Stephanie Damon-Moore, "Trial Judges and the Forensic Sciences Problem," *NYU Law Review* 92 (2017): 1570; "Trial judges are uniquely well positioned to staunch the flow of unreliable forensic evidence into court. . . . In order to do so, however, trial judges must break with sometimes-lengthy histories of admission, engage in a technical analysis outside the wheelhouse of most lawyers, and perhaps even face political backlash against an unpopular decision. As difficult as this may seem, none of the obstacles facing trial judges are insurmountable, and none exempt trial judges from their obligation to vigilantly gatekeep expert evidence in their courtrooms. . . . Now more than ever, trial judges must lead the way toward a better future for forensic evidence."

[19] See Peter J. Neufeld, "The (Near) Irrelevance of *Daubert* to Criminal Justice and Some Suggestions for Reform," *American Journal of Public Health* 95 (S1) (2005): S107, S109.

[20] *Lead Industries Association, Inc. v. Environmental Protection Agency*, 647 F.2d 1130, 1145 – 1146 (D.C. Cir. 1980).

[21] National Academy of Sciences, *Reference Manual on Scientific Evidence*, 3rd ed. (Washington, D.C.: National Academies Press, 2001), 9.

[22] Wendy E. Wagner, "Importing *Daubert* to Administrative Agencies through the Information Quality Act," *Journal of Law and Policy* 12 (2) (2004).

[23] Section 515(a) of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554).

[24] Office of Management and Budget, Executive Office of the President, "Final Information Quality Bulletin for Peer Review," *Federal Register* 70 (10) (January 14, 2005).

[25] Wagner, "Importing *Daubert*," 590 – 591 [see note 22].

[26] National Academies of Sciences, Engineering, and Medicine, *Optimizing the Nation's Investment in Academic Research* (Washington, D.C.: National Academies Press, 2016), 6.

[27] 21st Century Cures Act (Public Law 114-255).

[28] National Academies of Sciences, Engineering, and Medicine, *Optimizing the Nation's Investment in Academic Research*, 167 [see note 26].

[29] Its implementation has been twice postponed, and its full implementation is now scheduled for January 21, 2019. See Jerry Menikoff, Julie Kaneshiro, and Ivor Pritchard, "The Common Rule, Updated," *New England Journal of Medicine* 376 (2017): 613 – 615, wherein the authors state: "influential reports, including one from the National Academies of Sciences, Engineering, and Medicine, led to a long process of deliberation and discussion. The result is a final rule that differs significantly from what was initially proposed."

[30] National Academies of Science, Engineering, and Medicine, "International Summit on Human Gene Editing," http://nationalacademies.org/gene-editing/Gene-Edit-Summit/.

[31] Organizing Committee for the International Summit on Human Gene Editing, "On Human Gene Editing: International Summit Statement," December 3, 2015, http://www8.nationalacademies.org/onpinews/newsitem.aspx?RecordID=12032015a.

[32] Ibid.

[33] National Academies of Sciences, Engineering, and Medicine, *Human Genome Editing: Science, Ethics, and Governance* (Washington, D.C.: The National Academies Press, 2017).

[34] See Nuffield Council on Bioethics, *Genome Editing and Human Reproduction: Social and Ethical Issues* (London: Nuffield Council on Bioethics, 2018), http://nuffieldbioethics.org/wp-content/uploads/Genome-editing-and-human-reproduction-FINAL-website.pdf; and Association for Responsible Research and Innovation in Genome Editing (ARRIGE), https://arrige.org/.

[35] See The National Academies of Science, Engineering, and Medicine, "Second International Summit on Human Genome Editing," http://nationalacademies.org/gene-editing/2nd_summit/index.htm.

[36] United States Department of Justice, "Eyewitness Identification: Procedures for Conducting Photo Arrays," January 6, 2017, https://www.justice.gov/file/923201/download.

[37] Kelly M. Hoffman, Sophie Trawalter, Jordan R. Axt, and M. Norman Oliver, "Racial Bias in Pain Assessment and Treatment Recommendations and False Beliefs about Biological Differences Between Blacks and Whites," *Proceedings of the National Academy of Sciences* 113 (16) (2016): 4296 – 4301.

[38] Joe Davidson, "Feds Urged to Fight 'Unconscious Bias' in Hiring and Promotions," *The Washington Post*, April 14, 2016, https://www.washingtonpost.com/news/powerpost/wp/2016/04/14/feds-urged-to-fight-unconscious-bias-in-hiring-and-promotions/.

[39] See generally Jerry Kang, Mark Bennett, and Devon Carbado, "Implicit Bias in the Courtroom," *UCLA Law Review* 59 (2012): 1124; and Jerry Kang and Kristin Lane, "Seeing through Colorblindness: Implicit Bias and the Law," *UCLA Law Review* 58 (2010): 465.

[40] *Texas Department of Housing and Community Affairs v. Inclusive Communities Project*, 576 U.S. ___ (2015).

[41] Joan Johnson-Freese, "Build on the Outer Space Treaty," *Nature* 550 (7675) (2017): 182 – 184.