Discussion Draft for 9/22/14 ELI workshop; suggestions welcome.

Communicating Scientific Uncertainty: A Lawyer's Perspective

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I. Introduction

Humans instinctively want certainty. The world, however, is uncertain. Communicating intelligently is an everyday challenge. The challenge is daunting when the subject is technical and there are asymmetries among communicating parties. At any time among them, wide variations in skills, knowledge, information, experience, and belief impede effective communication. And over time, even a message that once successfully reached an audience may lose reliability, for example, peer-reviewed scientific studies published by respected journals that cannot be replicated.[1]

Uncertainty exists in many fields besides science, journalism, and law, for example, economics, medicine, national security, and poker, to name just four. There are various concepts and definitions of uncertainty.[2]

Definitions of uncertainty often refer to probability, which depends heavily on data from the past. Moreover, various existing matters are not yet discovered and various future effects are not predictable. My thumbnail definition is that uncertainty simply means lack of assurance.

The Working Group on Mitigation of Climate Change for the Intergovernmental Panel on Climate Change states that "'Uncertainty' denotes a cognitive state of incomplete knowledge that results from a lack of information and/or a disagreement about what is known or even knowable."[3] The Guidance Note for IPCC lead authors provides a "Likelihood Scale[4]:

Term	Likelihood of the outcome
Virtually certain	99-100% probability
Very likely	90-100% probability
Likely	66-100% probability
About as likely as not	33 to 66% probability
Unlikely	0-33% probability
Very unlikely	0-10% probability
Exceptionally unlikely	0-1% probability

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A scientist may think that "all scientific knowledge is uncertain" and that "experience with doubt and uncertainty is important."[5]

A tobacco or fossil fuel industry executive may think that "Doubt is our product since it is the best means of competing with the 'body of fact' that exists in the mind of the general public" and is "the means of establishing a controversy."[6]

The effectiveness of communications about uncertainty also turns on the relationships among the communicating parties and their underlying attitudes. An important recent study by Dr. Gretta Pecl and her colleagues at the Institute for Marine and Antarctic Studies at the University of Tasmania, http://www.imas.utas.edu.au/, shows that most rock lobster fishers in Tasmania view climate change as not occurring or as representing natural changes or cycles, and that they are reasonably confident in their ability to adapt as well as more concerned with business or other immediate pressures.[7]

Based on a conversation with Dr. Carla Guenther, Senior Scientist at the Penobscot East Resource Center in Stonington, Maine, http://www.penobscoteast.org, I understand that lobster fishermen in Maine may have comparable perceptions and adaptive approaches. Dr. Guenther also suggests considering the contrasting and instructive example of a lobster fisherman communicating with his personal physician about a diagnosis of cancer and attendant risks. There are differences that ought to enhance the effectiveness of the communication about risk and uncertainty in the physician-patient context including: the trusted relationship; the perceived competence, authority, and professional and ethical responsibility of the physician; the one-on-one nature of the communications; the personal severity, immediacy, and impact of the risk on the fisherman; and the possibility of surgical, pharmaceutical, and other remedial or palliative relief and attendant requirements for informed consent. The example of the physician-patient communication is instructive not only to show differences from general communications about climate change but also in another and disturbing way: Even with the differences, a recent study states that "Currently, patient-centered communications and shared decision making in oncology are suboptimal."[8] If communications in this one-on-one trusted context are suboptimal, is it any wonder that more general communications to the public or to particular groups about climate change often fail? As Dan Kahan (Professor of Law and Professor of Psychology at Yale Law School) states (in a draft essay based on remarks at the 2014 annual USDA_EPA Forestry and Agriculture Greenhouse Gas Modeling Forum): "The failure of widely accessible, compelling science to quiet persistent cultural controversy over the basic facts of climate change is the most spectacular science communication failure of our day."[9]

The psychology of communicating uncertainty is important to understand and study.

Whether a communication is calm and reasoned or strident and opinionated makes a difference. In my recent *Note to the Next Generation*, I said, "Even though the challenge was urgent, most people were not yet persuaded. Apocalyptic words were not effective to cause people preoccupied with varied stresses to pay attention to climate change and may even have fostered alienation, denial, and hostility."[10]

Communications about scientific uncertainty can become polarized and political, with zealous protestations and apocalyptic warnings on one side and self-serving justifications and denials on the other. Both are barriers not only to effective communication and understanding but also to reasoned discussion and possible intermediate approaches.

This workshop brings together scientists, journalists, and lawyers. Each group attempts to address issues of communicating about uncertainty. What follows is my perspective as a lawyer, first with a brief review of the legal system's ways of coping with uncertainty, and then of obstacles to communication as well as examples to consider for more effective communication.

II. Illustrative Standards, Rules, Norms, and Ethical Requirements

In general, courts, legislatures, and the legal profession attempt in various ways to address uncertainty, risk, unreliability, and incomplete information in a changing environment. They must do so within a system that has various objectives, including: determining responsibility and resolving adversarial litigation with finality and transparency; enabling transactions to be concluded with an enforceable contract; assuring the participants and the public a reasonable measure of fairness, acceptability, and predictability; and allocating decision-making authority to competent institutions and processes, including, as the case may be, courts, administrative agencies, elected executives, legislative bodies, and private ordering. For example:

The standard of proof

Varying standards of proof bear on the level of tolerable uncertainty, *e.g*, "reasonable doubt," "clear and convincing," and "preponderance of the evidence." Such standards are related to the interests at stake, whether life and liberty, or compensatory damages or other monetary relief such as restitution of unjust enrichment, or punitive damages. They are different from standards that may be used in other fields such as the "Likelihood Scale" used by the Intergovernmental Panel on Climate Change.

The admission of scientific evidence

The courts serve as gatekeepers to the admission of evidence, including scientific evidence. There are cases and guides to this much discussed topic, which will just be noted here.[11]

Temporary restraining orders and preliminary injunctions

A proceeding in which a party seeks a temporary restraining order or a preliminary injunction presents particular challenges in the context of uncertainty. By definition, such a proceeding occurs at or near the beginning of a case, before and while the facts and record are being developed and are uncertain. The court is asked to take or deny action that can be crucial and often decisive in the face of an insufficient record and substantial uncertainty.[12] The lawyer seeking such extraordinary relief should not exaggerate the claimed "emergency" or "irreparable harm" and the lawyer opposing it should not belittle it. They should both help the court understand the factual context and frame an order that addresses what is needed for the situation, if anything. When I taught Remedies at Berkeley Law (Boalt Hall) (1982-1989), I would develop these points in a class devoted to temporary restraining orders and preliminary injunctions and ask Judge Thelton Henderson of the U.S. District Court for the Northern District

of California to help me teach it. He would contribute his experience and views about the ethical, legal, and practical issues and bring the point home with the comment that when it came to lawyers who went over the line or got chalk on their shoes, "We talk about you in the lunchroom."

Constitutional rights and duties (selected examples and issues)

Various constitutional provisions bear on the issue of communicating scientific uncertainty:

- Under the First Amendment, scientists, lawyers, and others enjoy substantial freedom to express their views.
- Under the due process clauses of the Fifth and Fourteenth Amendments, prosecutors must disclose to defendants exculpatory and mitigating evidences (the *Brady* doctrine).[13]
- Under the Sixth Amendment, in a criminal prosecution, the defendant has the right to counsel (including issues of competent counsel), the right to trial by an impartial jury, and the right to have compulsory process for obtaining witnesses in the defendant's favor.
- Under the Seventh Amendment right to jury trial in civil cases, there are issues of presentation of scientific evidence to a lay panel, allocation of responsibility between judge and jury, and safeguarding of juror findings from reexamination.
- Under the Eighth Amendment, prohibition of cruel and unusual punishments, there are potential expert testimony issues regarding corrections and punishment and competency of the defendant.

Criminal law

In addition to constitutional rights and obligations, in the criminal law there are issues involving prosecutorial use of forensic evidence and exoneration by DNA evidence. The uncertainty that a defendant and counsel confront in considering a plea, sentence bargain, or defense and trial is aggravated by prosecutors' disregard of their constitutional and ethical obligations to disclose exonerating or mitigating evidence.[14]

Toxic Torts

The American Law Institute, before publishing the Restatement Third of Torts: Liability for Physical and Emotional Harm (2010), engaged deeply in its traditional process of drafting by expert reporters, review by expert advisers, intensive discussions by the governing Council and members. With regard to the difficult issues of toxic torts and causation, ALI representatives also met with scientists, primarily epidemiologists, at the National Academy of Sciences. The Restatement contains extensive comment on the subject.[15]

The Restatement also provides helpful comment questioning the concept of requiring an expert to testify to "reasonable medical or scientific certainty: ". . . [S]ome courts have employed a requirement that an expert testify that an opinion is held to a 'reasonable degree of medical [or scientific] certainty' for it to be admissible. This phrase implies a standard different from the preponderance requirement, suggests reliance on medical or scientific standards for proof, and seems to impose a high threshold for the opinion to be admissible. . . . Requiring an expert to state that an opinion is held to a medical or scientific certainty is problematic because the medical and scientific communities have no such 'reasonable certainty' standard. Thus for an expert to understand this standard, meaning must be provided by the attorney who hired the expert, by the expert's imagination, or by some other source outside the legal system. . . .

Moreover, the reasonable-certainty standard provides no assurance of the quality of the expert's qualifications, expertise, investigation, methodology, or reasoning. Thus, this Section adopts the same preponderance standard that is universally applied in civil cases. Direct and cross-examination can be employed to flesh out the degree of certainty with which an expert's opinion is held and to identify opinions that are speculative and therefore inadmissible.[16]

Products liability

A central problem in the law of products liability concerns design defects and attendant issues of uncertainty, risk assessment, and communication both to client manufacturers and by them to dealers and customers and, in the case of human pharmaceuticals, by manufacturers to doctors as "learned intermediaries." Attention is necessary to the questions whether a risk can be prevented or mitigated by design; and, if it cannot be prevented, whether and to what extent risk can be further reduced by warnings or user instructions or both. Overwarning is counterproductive.[17]

Contracts and certainty

Parties who are negotiating a contract involving scientific subject matter (or any matter) should keep in mind the fundamental requirement that the terms of a contract must be "reasonably certain."[18] "The terms of a contract are reasonably certain if they provide a basis for determining the existence of a breach and for giving an appropriate remedy."[19]

The special challenge of neonicitinoids and honey bees

Pesticides are the subject of statutes and regulations, administrative proceedings, court litigation, and extensive commentary. Relatively new nicotine-like insecticides called "neonicotinoids," or "neonics," for short, are the subject of intense controversy. They are blamed for causing or contributing to honey bee colony collapse disorder. They are also credited with causing or contributing to improved agriculture and being less harmful than preexisting insecticides.

Neonicotinoids have provoked complex scientific, policy, and legal issues involving causation, uncertainty, the precautionary principle, the proportionality principle, and various remedial approaches, including regulation and the development of good practices in the industry, with or without regulation.[20]

There are important differences between Europe and the United States. They are analyzed by a comparative scholar, Alberto Alemanno, who discusses the different perspectives, including the difference between "scientific insufficiency" and "scientific uncertainty."[21]

It is not my purpose here to address substantively the various statutes, regulations, administrative proceedings, and court cases that are relevant to neonicotinoids or express a view on them. Instead, I wish to comment briefly on the communication issue. Instead of polarizing accusations and zealous protests on the one hand or self-serving commendations and denials on the other, the subject is one for cordial exchanges of views; precision and comprehension in the gathering, analysis, reporting, and use of data; and consideration of the questions whether sensible intermediate approaches, including legal ones, are available between prohibition and unregulated use. Such approaches could involve targeted administrative regulations, guidelines,

or advisories as well as the application of good integrated pest management practices. For example, adjustments can be made regarding the timing and mode of application of the appropriate neonicotinoid. Regulators should monitor pesticide usage, study adverse effects reports, and make prompt adjustments when appropriate. For example, simple mechanical solutions to minimize the creation of toxic dust during the planting of treated seed have been demonstrated to mitigate the main complaint regarding neonics. There may also be approaches from other jurisdictions that should be considered.

The procedural context

The procedural context also bears on the issues. Cases involving high voltage power lines and electromagnetic radiation, of which there were once a flurry, offer an example: A person with a cancerous brain tumor who is seeking compensation in a court case might not be able to establish causation. A property owner, however, might be able to obtain property tax or eminent domain relief because psychological perceptions of risk have diminished market value. On the other hand, a public utility might have difficulty overturning an administrative decision that the power lines must be sited a certain distance away from a residential area; courts are reluctant to substitute judicial judgment for administrative agency discretion, and they provide leeway for administrative agencies to determine safe distances (and other matters) if they are otherwise within legal boundaries.[22]

Ethical rules

Ethical rules also bear on a lawyer's responsibilities to communicate with clients, courts, and others, while also serving as an advocate.

The American Bar Association's Model Rules of Professional Conduct (2014 Edition) serve as a model and are followed substantially or with variations in most U.S. jurisdictions. They were recently updated with the ABA's approval of recommendations from its Commission on Ethics 20/20 that was created to examine the impact of globalization and technology on the legal profession. They apply primarily to individual lawyers although in a very few jurisdictions they also apply to law firms. They bear directly or indirectly on a lawyer's competent understanding and communication of uncertainty and advice to clients about handling risk.[23]

A fundamental rule concerns competence: "**A lawyer shall provide competent representation to a client. Competent representation requires the legal knowledge, skill, thoroughness and preparation reasonably necessary for the representation."**[24] In addition to this black letter rule, the Model Rules provide comments, for example, Comment [8] provides: "To maintain the requisite knowledge and skill, a lawyer should keep abreast of changes in the law and its practice, including the benefits and risks associated with relevant technology, engage in continuing study and education and comply with all continuing legal education requirements to which the lawyer is subject."[25]

The model rules require that **"In representing a client, a lawyer shall exercise independent professional judgment and render candid advice. In rendering advice, a lawyer may refer not only to law but to other considerations such as moral, economic, social and political factors, that may be relevant to the client's situation."**[26] Under Comment [4], "Where consultation with a professional in another field is itself something a competent

lawyer would recommend, the lawyer should make such a recommendation. At the same time, a lawyer's advice at its best often consists of recommending a course of action in the face of conflicting recommendations of experts."

The model rules require candor to the tribunal.[27] On the specific subject of offering evidence, they provide that: **"A lawyer shall not knowingly: . . . offer evidence that the lawyer knows to be false. If a lawyer, the lawyer's client, or a witness called by the lawyer, has offered material evidence and the lawyer comes to know of its falsity, the lawyer shall take reasonable remedial measures, including, if necessary disclosure to the tribunal. A lawyer may refuse to offer evidence, other than the testimony of a defendant in a criminal matter, that the lawyer reasonably believes to be false. . . ."**[28]

The model rules also impose specific obligations on prosecutors with regard to forensic evidence and disclosure of exculpatory and mitigating evidence.[29]

The ABA Committee on Ethics and Professional Responsibility has just issued a formal opinion on the managerial and supervisory obligations of prosecutors.[30] It takes into account "the frequency of prosecutorial conduct nationwide documented by, *inter alia*, opinions in criminal cases and disciplinary proceedings in the last fifteen years . . . [that] reveal numerous violations of *Brady* (which are also violations of Rule 3.8), and show other examples of misconduct, e.g., prosecutors using false evidence or failing to correct false statements to the court, prosecutors engaged in other improper courtroom conduct, and prosecutors engaging in conduct that would violate" other rules.

III. Obstacles to Communicating about Scientific Uncertainty

As between scientist and lawyer or scientist and tribunal

The different standards of proof or truth, knowledge, and authority to make a decision in the face of some degree of uncertainty provide a challenge and sometimes an obstacle to effective communication. "Expert witnesses speak science to law. When scientists testify in court, they speak from one language into another, one profession into another, one discipline into another, one culture into another. To inform the fact-finder effectively, and to treat the witness and the judicial process fairly, lawyers need to understand the legal and scientific significance of how expert witnesses speak science."[31]

As between lawyer and journalist

The lawyer needs to understand the journalist's need to meet deadlines and to communicate accurately, succinctly, and clearly. The journalist needs to understand that the lawyer may be acting as an advocate for a client and must abide by ethical rules including confidentiality. Based on personal experience with various media, both lawyer and journalist need to understand the opportunities and limitations of the particular media they are using. For example, print journalists and, in some cases, radio journalists, and sometimes TV talk show hosts or interviewers, may provide an opportunity to explore a subject in a conversational, rational, and give-and-take way that enhances public understanding. On the other hand, a lawyer advocate being interviewed for a headline news item on a program that will likely air just a snippet or soundbite has to be especially careful not to have a single remark or clause taken out

of context, particularly in a way that might undermine or be misconstrued against his client's cause.

As between scientist and journalist

The U.S. Climate Change Program offers useful comments, for example: *e.g.*: "Uncertainty offers the opportunity for various interests to confuse and divert the public discourse in what may already be a very difficult scientific process of seeking improved insight and understanding. In addition, many reporters are not in a position to make their own independent assessment of the likely accuracy of scientific statements. They have a tendency to seek conflict and report 'on the one hand, on the other hand,' doing so in just a few words and with very short deadlines. . . . '[S]trong peer pressure . . . against becoming a visible scientist who communicates with the media and the public,' . . . combined with an environment in which there is high probability that many statements a scientist makes about uncertainties will immediately be seized on by advocates in an ongoing public debate, it is perhaps understandable that many scientists choose to just keep their heads down, do their research, and limit their communications to publication in scientific journals and presentations at professional scientific meetings."[32]

Partisan political divisions as a barrier to communication

In the United States, the problem of communication within and across disciplinary areas is aggravated by partisan political divisions. A recent Pew Research report includes a comparison of partisan differences in views of the following global threats: Iran's nuclear program, China's emergence as a world power, the conflict between Israelis and Palestinians, Islamic extremist groups like al Qaeda, the Islamic militant group in Iraq & Syria, known as ISIS, North Korea's nuclear program, growing tension between Russia and its neighbors, the rapid spread of infectious diseases from country to country, and global climate change. On global climate change, only 25% of Republicans say it is a "major threat" to the U.S. while 68% of Democrats say it is, and 44% of Independents say it is, with a Republican-Democratic difference of -43. To illustrate how wide this division is, the next greatest difference was +18 with 74% of Republicans saying Iran's nuclear program is a "major threat" and 56% of Democrats saying so (and 54% of Independents).[33]

IV. Examples of communicating about uncertainty

Communicating about uncertainty should not be just a one-sided or one-way matter. It can and often should involve both the communicator and the recipient interactively. A recent example concerns climate change and its effect on fisheries along the 60,000 miles of Australian coastline. "Redmap," the Range Extension Database and Mapping Project, involves fishermen, scientists, and others in keeping current an online map of how species distributions may be changing in response to climate and related information. This engages fishers, divers, and the broader community in the building of the knowledge base and creates a sense of public ownership of the information generated, facilitating shared understanding. *See* http://www.redmap.org.au.

The Institute for Marine and Antarctic Studies at the University of Tasmania and others are centrally involved in this project. They are also developing a Global Marine Hotspots Network,

a communication network involving scientists, resource managers, and other stakeholders from rapidly warming regions. A key idea of the network is that "Research, development, management and communication can all be delivered faster and with greater certainty through a coordinated network across global hotspots."[34]

The Center for Research on Environmental Decisions has recently published The Psychology of Climate Change Communications: A Guide for Scientists, Journalist, Educators, Political Aides, and the Interested Public (2009). Its recommendations include encouraging group participation.[35]

Two additional approaches that bear attention are suggested by Professor Dan Kahan: "One method, examined in depth by Geoffrey Cohen, is to present information in a manner that affirms rather than threatens people's values. . . . The second technique for mitigating public conflict over scientific evidence is to make sure that sound information is vouched for by a diverse set of experts. . . . We need to learn more about how to present information in forms that are agreeable to culturally diverse groups, and how to structure debate so that it avoids cultural polarization. If we want democratic policy-making to be backed by the best available science, we need a theory of risk communication that takes full account of the effects of culture on our decision-making."[36]

As we improve our communications, we need to pay attention also to improving our instrumentation, measurement, and public reporting of greenhouse gas emissions. Better data should lead to better communications as well as citizen use of the data. We should also consider making more effective use of third party verification methods to ensure accuracy while reducing administrative burdens on regulators.[37] A simple example is to advance from an antiquated era in which cows are visually counted to determine methane emissions to a twenty-first century era in which advanced and available technologies are used.

Lastly, it is important not to exaggerate uncertainty or besiege people with doomsday stories. Whether the subject is climate change or honey bees, the public will be served by rational discussion and exploration of pragmatic approaches.

Appendix I: **Selected Excerpts on the Meaning of Uncertainty**

- The U.S. Climate Change Program, *Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making* (Jan. 2009), discusses sources and types of uncertainty, the importance of quantifying uncertainty, cognitive challenges in estimating uncertainty, statistical methods and models, methods for estimating uncertainty, propagation and analysis of uncertainty, making decisions in the face of uncertainty, communicating uncertainty, and guidance for researchers.

- The concept of "deep uncertainty" is described as occurring "when the parties to a decision do not know—or agree on—the best model for relating actions to consequences in the likelihood of future events." RAND, Research Highlights, *Making Good Decisions Without Predictions: Robust Decision Making for Planning Under Deep Uncertainty*, http://www.rand.org/pubs/research_briefs/RB9701.html . *See also*, Paul K. Davis, *Lessons from RAND's Work on Planning Under Uncertainty for National Security* (2012), http://www.rand.org/pubs/technical_reports/TR1249.html ("A first step in dealing with uncertainty is confronting its existence, ubiquity, and magnitude. A second step is dealing with it when informing assessments and decisions"). "It may be helpful to start with definitions and because risk and uncertainty are tightly bound in common language to introduce them together. Uncertainty: A primitive concept meaning a state of limited knowledge or of indecision. It is useful to distinguish between normal uncertainty and deep uncertainty. The former applies when we understand a phenomenon and how to value outcomes. Under this condition we can address uncertainty with standard versions of sensitivity analysis or probabilistic analysis . . . . Deep uncertainty is the condition where we do not know with confidence the model by which to describe the phenomenon of interest, the relevant probability distributions, or how to value the outcomes. Risk: the potential for something adverse to happen. The extent of risk depends on the likelihood of bad developments and the consequences if they occur. . . ." *Id.* at 1.

- "Policy-making is often focused on cases where there is confidence that major changes are likely to occur, while there is very limited ability to quantify the impacts of those changes for people. There are at least four relevant varieties of uncertainty in this case . . . and they are not mutually exclusive: imprecision, ambiguity, intractability and indeterminacy." Leonard A. Smith and Nicholas Stern, *Uncertainty in science and its role in climate policy*, 369 Phil. Trans. R. Soc. 1, 4 (2011).

- George Marshall, founder of the Climate Outreach and Information Network, based in Oxford, England, in his new book, Don't EvenThink About It: Why Our Brains Are Wired to Ignore Climate Change (2014), states that uncertainty is "likely to be a major reason why people ignore climate change. In experiments, uncertainty about future outcomes is one of the key factors that lead people to act in their own short-term self interest. Policy makers and campaigners on all sides understand very well the importance of uncertainty in regard to action. This is why the U.N. Framework Convention on Climate Change expressly states, in its third principle, that a 'lack of full

scientific certainty should not be used as a reason for postponing measures' to minimize the causes of climate change. And this is why President George W. Bush excused his inaction on the issue by saying that 'no one can say with any certainty what constitutes a dangerous level of warming, and, therefore, what level should be avoided. The main source of public uncertainty, though, relates to the widespread perception that scientists are themselves divided on the issue." *Id.* at 72.

- "Uncertainty Typology" is discussed in a recent book on adapting to an uncertain climate: "There is a distinction between various sources of uncertainty: decision uncertainty (*e.g.* related to human decisions that determine future GHG and aerosol particle emissions), natural variability (*e.g.* related to the internal variability of the climate system), and scientific uncertainty (*e.g.* related to data gaps, incomplete understanding or insufficient computing power of climate and climate impact models"). Leendert van Bree and Jeroen van der Sluijs, *Background on Uncertainty Assessment Supporting Climate Adaption Decision-Making*, Chapter 2 in Tiago Capela Lourenco et al (eds.), Adapting to an Uncertain Climate 23 (2014). "Decision-making on adaptation under climate uncertainty also involves effective communication and appreciation between science, society, and policy. Such communication and appreciation is often hampered by misunderstandings about the phenomenon of uncertainty in the science and the fundamental limits to climate change and impact predictions." *Id.*

- Uncertainty is inevitable. In the preliminary description of error analysis in his leading text, John R. Taylor states that "In science, the word *error* does not carry the usual connotations of the terms *mistake* or *blunder*. Error in a scientific measurement means the inevitable uncertainty that attends all measurements." John R. Taylor, An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements 3 (2d ed. 1997). "Error analysis is the study and evaluation of uncertainty in measurement. Experience has shown that no measurement, however carefully made, can be completely free of uncertainties. Because the whole structure and application of science depends on measurements, the ability to evaluate these uncertainties and keep them to a minimum is crucially important." *Id.*

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- Gretta Pecl et al, *The East Coast Tasmanian Rock Lobster Fishery: Vulnerability to Climate Change Impacts and Adaptation Response Options*, Executive Summary (2009)
- Gretta T. Pecl, Alistair J. Hobday, Stewart Frusher, Warwick H.H. Sauer, and Amanda E. Bates, *Ocean warming hotspots provide early warning laboratories for climate change impacts*, 24 Rev. Fish Biol. Fisheries 409 (2014)
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- Royal Society, *Special Issue on 'Handling Uncertainty in Science'* (2011)
- Thomas C. Schelling, The Strategy of Conflict (1960)
- Thomas C. Schelling, *Thomas C. Schelling on Climate Change*, Interview with Conor Clark, Economist's View (Jul. 18, 2009)

- Thomas C. Schelling, *Uncertainty and Action on Climate Change*, Project Syndicate (Jan. 7, 2008): "As more becomes known about climate change – for example, the role of clouds and oceans – more uncertainties emerge. Nevertheless, the greenhouse 'theory,' as it is sometimes disparagingly been called, has been established beyond reasonable doubt. There is uncertainty about the quantitative parameters, and there can be doubt about whether the warming of recent decades is entirely due to the 'greenhouse effect.' But the basics of global warming are not in scientific dispute."
- Leonard A. Smith and Nicholas Stern, *Uncertainty in science and its role in climate policy*, 369 Phil. Trans. R. Soc. A. 1-24 (2011)
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- John R. Taylor, An Introduction to Error Analysis: The Study of Uncertainties in Physical Measurements (2d ed. 1997)
- U.S. Climate Change Science Program, Best Practice Approaches for Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Change Decision Making (Jan. 2009) (Chapter 8, pp. 67-70, deals with "Communicating Uncertainty")
- Herbert I. Weisberg, Willful Ignorance: The Mismeasure of Uncertainty (2014)
- Wikipedia, *Affect Heuristic* ("a mental shortcut that allows people to make decisions and solve problems quickly and efficiently, in which current emotion—fear, pleasure, surprise, etc.—influences decisions")

Endnotes

[1] *See, e.g.*, Editorial, *Announcement: Reducing our irreproducibility,* 496 Nature 398 (Apr. 25, 2013); Editorial, *Error Prone, 487 Nature 406* (Jul. 26, 2012); Editorial, *Further confirmation needed*, 30 Nature Biology 806 (2012); Bruce Booth, *Science Being Studied: Replication, Publication, and Resource Allocation*, Forbes (Nov. 8, 2013) (also discussing the Reproducibility Initiative); George Johnson, *New Truths That Only One Can See*, NY Times (Jan. 20, 2014).

[2] Excerpts from recent studies are appended.

[3] Working Group III, Intergovernmental Panel on Climate Change, Mitigation of Climate Change, Chapter 2, *Integrated Risk and Uncertainty: Assessment of Climate Change Program Policies*, p. 6 (2014)

[4] Guidance Note for Lead Authors of the IPCC Fifth Assessment Report on Consistent Treatment of Uncertainties, p. 3 (2010)

[5] For example, in his lecture on *The Uncertainty of Science*, Richard Feynman said: Scientists "are used to dealing with doubt and uncertainty. All scientific knowledge is uncertain. This experience with doubt and uncertainty is important. I believe that it is of very great value, and one that extends beyond the sciences. I believe that to solve any problem that has never been solved before, you have to leave the door to the unknown ajar. You have to permit the possibility that you do not have it exactly right. Otherwise, if you have made up your mind already, you might not solve it." Richard Feynman, *The Uncertainty of Science*, in The Meaning of it All: Thoughts of a Citizen Scientist 26-27(1998)*; see* James Glieck, Genius: The Life and Times of Richard Feynman 171 (1992) ("He believed in the primacy of doubt, not as a blemish on our ability to know, but as the essence of knowing").

[6] "Doubt is our product since it is the best means of competing with the 'body of fact' that exists in the mind of the general public. It is also the means of establishing a controversy. Within the business we recognize that a controversy exists. However, with the general public the consensus is that cigarettes are in some way harmful to the health. If we are successful in establishing a controversy at the public level, then there is an opportunity to put across the real facts about smoking and health. Doubt is also the limit of our 'product.' Unfortunately, we cannot take a position directly opposing the anti-cigarette forces and say that cigarettes are a contributor to public health. No information that we have supports such a claim." Brown & Williamson, *Smoking and Health Proposal*, B&W Document No. 332506, http://tobaccodocuments.org/bw/332506.html, attributed to R.A. Pittman, Senior Brand Marketing Supervisor at B&W from 1968-70 with help from B&W marketing executives John Blalock, Charles I. McCarty, and Corny Mujie, *see* http://tobaccodocuments.org/landman/332506.html. *See also* David Michaels and Celeste Monforton, *Manufacturing Uncertainty: Contested Science and the Protection of the Public's Health and* Environment, 95 Am. J. Pub. Health S339-48 (Supp. No. 1, 2005); Naomi Oreskes and Erik M. Conway, Merchants of Doubt: How a Handful of Scientists Obscured the Truth from Tobacco Smoke to Global Warming 10-35 (2010) (Chapter 1, "Doubt Is Our Product").

[7] *See* Melissa Nursey-Bray, Gretta T. Pecl, et al, *Climate Change Risk Perceptions and Rock Lobster Fishers, Tasmania*, 36 Marine Policy 753 (2012). "The risk perception study provided a contrast to the scientific evidence for past, present and future climate impacts on rock lobster and the fishery. . . . First, in relation to climate change, 18 of the 22 (just under 80%) fishers viewed climate change as either not occurring or as representing natural changes or cycles. Second, fisher descriptions of observed changes in their fishing areas over time revealed clear synergies with scientific observations. Third, interviews demonstrated that fishers considered climate change as a secondary risk to their businesses given the ongoing regulatory environment, issues around successional planning and debt within the industry. Finally, fishers seemed to feel that the industry was naturally volatile and fishers had adaptive capacity, which mediated in large part any concern over climate change." *Id.* at 755. The study was initiated by the Institute for Marine and Antarctic Studies at the University of Tasmania, which is also the national host for Redmap, http://www.redmap.org.au, and a leader of the developing Global Marine Hotspots Network.

[8] *See* Laura Levit, Erin Balogh, Sharyl Nass, and Patricia A. Ganz (Eds.), Delivering High-Quality Cancer Care: Charting a New Course for a System in Crisis, Chapter 3, *Patient-Centered Communications and Shared Decision Making* (2013); *see also* Lyn Paget et al, Patient-Clinician Communication: Basic Principles and Expectations (June 2011), discussion paper at the Institute of Medicine Roundtable on Value & Science Driven Health Care.

[9] Dan M. Kahan, *Climate Science Communication and the Measurement Problem*, http://ssrn.com/abstract=2459057, p. 2 (2014).

[10] Michael Traynor, *Note to the Next Generation*, 28 Environmental Forum 42, 45 (2011).

[11] *See, e.g., Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579 (1993); Federal Judicial Center, Reference Manual on Scientific Evidence (3rd ed. 2011); Carol Henderson, Cynthia H. Cwik, and Jules A. Epstein, Scientific Evidence Review: Admissibility and the Use of Expert Evidence in the Courtroom, Monograph #9 (2013).
[12] *See, e.g.*, John Leubsdorf, *The Standard for Preliminary Injunctions*, 91 Harv. L. Rev. (1978).
[13] *See, e.g., Brady v. Maryland*, 373 U.S. 83 (1963).
[14] A recent example of wrongful conviction and imprisonment due to "proof" by "science" and eventual exoneration by science, *i.e.*, DNA evidence that led to the actual murderer and to a confession by him that he acted alone, involves the two recent exonerations in Mississippi of Kennedy Brewer and Levon Brooks. To obtain the convictions eventually held wrongful, the prosecutor had used a forensic pathologist who was not board certified in forensic pathology and was known to conduct approximately six times as many autopsies per year than the professional standard (*i.e*., 1200-1800 instead of 250) and a forensic odontologist to testify to so-called "matching" bite marks. Because of the effective work of the Mississippi Innocence Project, the exonerations occurred. A friend who formerly worked at the Project informs me that the case is not unique, that convictions and incarcerations resulting from bias and the manipulation of "science" are commonplace in Mississippi, and raises the question: "How can we use science to advance justice while acknowledging that scientific theories may be based, to some extent, on proof but are not inherently Truth?"
The problem of convicting people on the basis of "scientific evidence" and later exonerating them on the basis of DNA evidence and related issues is helpfully addressed by Judge Harry T. Edwards, *The National Academy of Sciences Report on Forensic Sciences: What It Means for the Bench and Bar*, 51 Jurimetrics 1 (2010) (Judge Edwards served as Co-Chair for the NRC Forensic Science Report).
[15] Restatement Third of Torts: Liability for Physical and Emotional Harm, § 28, Comment *c.*
[16] *Id.*, Comment *e.*
[17] *See generally* Restatement Third of Torts: Products Liability (1998).
[18] Restatement Second of Contracts § 33(1) (1981).
[19] *Id.* § 33(2).
[20] My brother Joe Traynor is a soil technologist and bee broker and his company, Scientific Ag Co., provides honeybees for almond growers and others; he is frequently quoted. I have been in regular communications with him and Randy Oliver, who maintains an informative website at http://scientificbeekeeping.com, and is recognized as a leader among those wanting to bring the best information as well as common sense to this complex challenge.
[21] *See* Alberto Alemanno, *The Science, Law and Policy of Neonicotinoids and Bees: A New Test Case for the Precautionary Principle*, 4 European J. of Risk Regulation 191 (2013).
[22] *See, e.g.*, Edward Gerjuoy, *Electromagnetic Fields, Biology and Law*, 35 Jurimetrics J. 55 (1994); Alex Kozinski (Moderator), *Round Table Discussion: Science, Environment and the Law*, 21 Ecology L. Q. 343, 344 (1994).
[23] In addition to the rules specifically quoted and discussed in text, *see* scope of representation and consultation with client (1.2); diligence and promptness (1.3); communication (1.4); Confidentiality (1.6); Conflict of interest and attendant appreciation of risk and informed consent issues (1.7, 1.8); Client with diminished capacity (1.14); Evaluation for use by third persons (2.3); Lawyer as third-party neutral and communication of difference from role as representing a client (2.4); Meritorious claims and contentions (3.1); Fairness to opposing party and counsel, including duties re evidence (3.4); Impartiality and decorum and prohibition against unauthorized ex parte communications (3.5); Trial publicity (3.6); Lawyer as witness (3.7); Advocate in nonadjudicative proceedings (3.9); Truthfulness in statements to others (4.1); Communication with person represented by counsel (4.2); Dealing with unrepresented person (4.3); Responsibilities of partners, managers, and supervisory lawyers (5.1); Responsibilities regarding nonlawyer assistance (5.3); Professional independence (5.4); Unauthorized practice of law (5.5); Responsibilities regarding law-related services (5.7); Communications concerning a lawyer's services (7.1); Advertising (7.2); Solicitation of clients (7.3); Communication of fields of practice and specialization (7.4); Reporting professional misconduct (8.3);
Misconduct, including dishonesty, fraud, deceit, or misrepresentation (8.4).
[24] Model Rule 1.1.
[25] *See, e.g.*, Gail Bingham, Pamela Esterman, and Christopher Ritt, *Effective Representation of Clients in Environmental Dispute Resolution*, 27 Pace Envtl L. Rev. 61 (2009).
[26] Model Rule 2.1.
[27] Model Rule 3.3.

[28] Model Rule 3.3, subd. (3). Comment [8] provides that "The prohibition against offering false evidence only applies if the lawyer knows that the evidence is false. A lawyer's reasonable belief that evidence is false does not preclude its presentation to the trier of fact. A lawyer's knowledge that evidence is false, however, can be inferred from the circumstances. See Rule 1.0(f) ["a person's knowledge can be inferred from circumstances"]. Thus, although a lawyer should resolve doubts about the veracity of testimony or other evidence in favor of the client, the lawyer cannot ignore an obvious falsehood." *See, e.g.*, David S. Caudill, *Lawyers Judging Experts: Oversimplifying Science and Undervaluing Advocacy to Construct an Ethical Duty?*, 38 Pepperdine L. Rev. 675, 684-689 (2011).

[29] Model Rule 3.8: **"The prosecutor in a criminal case shall: . . . (d) make timely disclosure to the defense of all evidence or information known to the prosecutor that tends to negate the guilt of the accused or mitigates the offense, and, in connection with sentencing, disclose to the defense and to the tribunal all unprivileged mitigating information known to the prosecutor, except when the prosecutor is relieved of this responsibility by a protective order of the tribunal; . . . ."**

[30] Formal Opinion 467, Sept. 8, 2014.

[31] Deborah M. Hussey Freeland, *Speaking Science to Law*, 25 Georgetown Int'l Envtl. L. Rev. 289, 290 (2013).

[32] U.S. Climate Change Science Program**,** Best Practice Approaches in Characterizing, Communicating, and Incorporating Scientific Uncertainty in Climate Decision Making, Chapter 8, *Communicating Uncertainty*, pp. 69-70 (Jan. 2009).

[33] *See* Pew Research Center for the People & the Press, *As New Dangers Loom, More Think the U.S. Does 'Too Little' to Solve World Problems* (Aug. 28, 2014); Judith Curry, Interview on Science Communications (Aug.27, 2014) ("Climate science has become hotly politicized, with many scientists playing an adversary role"). I note but do not attempt to develop the separate question whether and to what extent gender discrimination is a barrier to effective communication within and across disciplines. *See, e.g*, Mary Beard, *The Public Voice of Women*, 36 London Rev. of Books 11 (Mar. 20, 2014), http://www.lrb.co.uk/v36/n06/mary-beard/the-public-voice-of-women; Matt Shipman, *Gender Bias in Researcher-to-Researcher Communication* (Mar. 22 2013), http://www.scilogs.com/communication_breakdown/gender-bias-study-2013/.

[34] Stewart Frusher, Gretta Pecl, Alistair Hobday, and Warwick Sauer, *A Global Network of Marine Hotspots*; Gretta T. Pecl, Alistair J. Hobday, Stewart Frusher, Warwick H.H. Sauer, and Amanda E. Bates, *Ocean warming hotspots provide early warning laboratories for climate change impacts*, 24 Rev. Fish. Biol. Fisheries 409 (2014) (emphasizing "the need for trans-disciplinary and participatory approaches to effectively engage stakeholders"); Alistair J. Hobday and Gretta T. Pecl, *Identification of global marine hotspots: sentinels for change and vanguards for adaptation action*, 24 Rev. Fish Biol. Fisheries 415 (2014) ("Developing a network of scientists, resource managers and policy makers working in global marine hotspots, where information is integrated and synthesized, contrasted and compared across locations provides, us, globally, with critical learning opportunities to address the immediate and future challenges of climate change").

[35] *Id.* at 33-36.

[36] Dan Kahan, *Fixing the Communications Failure*, 463 Nature 296-297 (2010).

[37] "Choosing a culture of science in which independent validation becomes a primary criterion for scientific acceptance will help to regain public trust. . . .In a world of cheap and plentiful data, it should become feasible to institutionalize some forms of routine independent validation. Eventually, methods and standards for replication of study results will evolve. Proper validation will become an essential component of research activity. . . ." Herbert J. Weisberg, Willful Ignorance: The Mismeasure of Uncertainty 363-364 (2014); Cynthia Giles, Assistant Administrator for the Office of Enforcement and Compliance, EPA, *Next Generation Compliance*, Environmental Forum 22 (Sept./Oct. 2013), and appendix of annotations and references, including third party verification, at http://www2.epa.gov/sites/production/files/2013-08/documents/giles-next-gen-article-forum-eli-sept-oct-2013-appendix.pdf.