The Epistemology of Scientific Evidence

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In place of the traditional epistemological view of knowledge as justified true belief we argue that artificial intelligence and law needs an evidence-based epistemology according to which scientific knowledge is based on critical analysis of evidence using argumentation. This new epistemology of scientific evidence (ESE) models scientific knowledge as achieved through a process of marshalling evidence in a scientific inquiry that results in a convergence of scientific theories and research results. We show how a dialogue interface of argument from expert opinion, along with its set of critical questions, provides the argumentation component of the ESE. It enables internal scientific knowledge to be translated over into a wider arena in which individual non-expert citizens and groups can make use of it. The external component shows how evidence is presented and used in a legal procedural setting that includes fact-finding, weighing the credibility of expert witnesses, and critical questioning of arguments. The paper critically reviews the standards of admissibility of scientific evidence using the ESE.

Keywords: scientific evidence, evidence-based epistemology, argumentation, expert opinion testimony, Carneades Argumentation System, standards of admissibility.

I. INTRODUCTION

Laudan (2006, 20) tells us that although theorists of knowledge routinely examined truth-seeking practices in science and mathematics, legal epistemology scarcely exists as a recognized area of inquiry. He underscores this point by entitling his book *Truth, Error and Criminal Law: an Essay in Legal Epistemology.* On the other hand, issues of legal epistemology are coming more and more to the forefront in artificial intelligence and law, with the advent of argumentation models of evidential reasoning in law. Argumentation systematically adopts what would be called from the viewpoint of traditional epistemology a *skeptical point of view*, holding that knowledge of the truth is hard to come by under conditions of uncertainty, inconsistency and employment of defeasible arguments of the kind typically used in a trial setting, like argument from expert opinion and argument from witness testimony.

According to Allen (1994, 633), "the defining trait of litigation is decision under uncertainty". A second trait is that the decision is reached by an uninvolved third party that has to evaluate reported events rather than by having direct access to the events themselves as they happen. These traits suggest that an epistemology requiring true belief is inapplicable in a realistic way to the evaluation of evidence that takes place at trial. As Allen (1994, 633) put it, "there is often a considerable distance between the actual event and the decision about that event". To deal with evaluation of evidence in this kind of situation, an epistemology based on justifiable acceptance is much more appropriate than one based on justified true belief. What is required is an epistemology based on evidence rather than one requiring a finding to be a true belief. Stein (2005, 119) reinforces this view in his contention that fact-finders make their findings under uncertainty by determining probabilities of the relevant facts, probabilities not based on the notion of Pascalian probability, but on a different notion of probability called Baconian probability by Cohen (1977). Baconian probability is evidence-based, and therefore has different rules for combining propositions evidentially than those used in the Bayesian calculus with its rules for negation and conjunction.

According to the traditional epistemological theory, knowledge is defined as justified true belief. According to the new view of evidence-based epistemology proposed by Cohen, Allen and Stein, because of the defeasible nature of evidential reasoning, both in science and in law, knowledge is evidence-based but inherently prone to the possibility of error. On this view, even in science we can never say with complete certainty that a scientific hypothesis has been proven beyond all doubt (Walton, 2011). Hence the propositions supported by evidence, or proved to be true according to standards of proof, are accepted as true, rather than being believed to be true. The matter of which philosophical framework to adopt, the traditional view of knowledge as justified true belief or the more recent view of knowledge as evidence-based argumentation, has great significant implications for the field of artificial intelligence and law. This is especially the case since argumentation has become a central model for evidential reasoning in the field of artificial intelligence and law (Bench-Capon, 1997). Argumentation as a model of rational thinking works by examining the pro and contra evidence-based arguments on both sides of an issue, under conditions of uncertainty and lack of knowledge insufficient to prove the disputed claim beyond all doubt. The new technologies being developed in artificial intelligence and law, based on the argumentation model, fit well with new evidence-based view of epistemology. As will be shown in this paper, artificial intelligence and law can both make contributions to, and profit from, such an acceptance-based and evidence-based theory of knowledge.

The scholars who dominated evidence scholarship in the first half of the twentieth century, for example John H. Wigmore, were the architects of the modern law of evidence. They were examining the foundations of knowledge, but they were primarily practitioners whose primary work and interests were not in building epistemological theories for philosophy (Tillers, 1989, 1226). On these foundations, the grounds of fact-finding can be divided into two parts: epistemic grounds and non-epistemic grounds. The non-epistemic grounds comprises non-epistemic policy values, including the efficient use of resources, the protection of the rights of those accused of a crime, and various other social goods, such as the sanctity of marriage (spouses cannot be made to testify against one another) or preserving good relations with other nations (diplomats cannot generally be convicted of crimes, however inculpatory the evidence) (Laudan, 2008, 2). We will show in this paper, however, that the trial is fundamentally an epistemological event, (Pardo, 2005, 853) in which scientific knowledge, itself based on evidence, is re-used as legal evidence. But there are some scholars take different viewpoints. For example, Redmayne argues that "questions about inquiry are not really epistemological at all" (Redmayne, 2003, 853). Because the factual truths in dispute often go beyond what the fact-finders can be expected to know, tribunals have come to increasingly depend upon scientific evidence for determining the facts in the cases. In the January 22, 1995 issue of *New Law Journal*, William T. Pizzi remarked that in the United States trial by jury is becoming trial by expert (Pizzi, 1995, 82). We could go so far as to say without hyperbole that seeking truth by using scientific evidence is becoming the main way to determine the facts in dispute in modern litigation. The problem of the epistemological structure of scientific evidence is posed by these observations (Kesan, 1995, 2006).

We provide an epistemological model of scientific evidence that is different from the traditional approach that has dominated analytical philosophy in the second half of the twentieth century, and still does. Our approach is different from the traditional justified-belief-plus approach in that it looks at how a proposition is proved as knowledge in two settings, science and law, and how knowledge is transferred as evidence from the one truth-finding procedural setting to the other. Instead of taking epistemology to be a purely theoretical philosophical subject, we take it to be a practical multidisciplinary subject that defines knowledge in the context of an established procedural setting that purports to be able to prove or disprove hypotheses and claims. If the study of how scientific evidence should be evaluated becomes a multidisciplinary subject (Beecher-Monas, 2007) then the area of study we call the epistemology of scientific evidence (ESE) should become an interdisciplinary field of research concerned with science, law, philosophy of science, artificial intelligence, logic and epistemology. Based on this presumption, the theoretical background of the ESE is introduced in Part Ⅱ. Part Ⅲ analyzes the structure of the ESE.

Ⅱ. THE THEORETICAL BACKGROUND OF THE ESE

A. *Science and Law: Two Types of Epistemic Models for Truth-seeking*

In current litigation in which fact-finding is more and more dependent on ever-changing scientific evidence, people are more likely to commit epistemological questions to the scientific community's care. But, in fact, there are discernible differences between the epistemological principles that scientists use during their scientific research and discovery and principles that fact-finders use when they evaluate scientific evidence during the fact-finding process. It can be said that both the legal system and science aim at seeking truth, but they do so in very different ways: truths are *determined* by advocacy in the legal system and *discovered* by inquiry in science. An inquiry is a very different enterprise from advocacy: a scientific inquiry represents an attempt to discover the truth of some questions. The obligation of a scientist is to seek out all the evidence he can, to assess its worth as impartially as possible, and to draw conclusions only if the evidence warrants doing so. Advocacy is an attempt to make a case for the truth of some claim and the obligation of an attorney is to seek out evidence favoring the proposition in question, while the obligation of trier is to judge which side has met its burden of persuasion (Haack 2003, 207). But it should be noted that the course of fact-finding based on scientific evidence never ends, even though it can end in knowledge once scientific acceptance has converged, whereas the truth in legal process has to be proved within relatively short time frame.

1. The Carrier of Scientific Truth: Scientific Knowledge

As a starting point, the term 'science' can be used as meaning "systematized knowledge derived from observation, study and experimentation carried on in order to determine the nature or principles of what is being studied".[1] Science is methodology, a practical way of finding reliable answers to questions we may ask about the world around us. It is also defined as"the use of evidence to construct testable explanationsand predictions of natural phenomena, as well as the knowledge generated through this process" (NAS 2008, 10)[2].In other words, science is a particular way of knowing about the world. In science, explanations are restricted to those that can be inferred from confirmable data—the results obtained through observations and experiments that can be substantiated by other scientists. Anything that can be observed or measured is amenable to scientific investigation. Explanations that cannot be based on empirical evidence are not a part of science.[3] Scientific activity derives from observation, but observation alone could not result in scientific knowledge. To some extent scientific knowledge is not established by constructing but by discovering scientific facts. And scientific discovery that mostly begins from inspiration and intuition works as a logical process of putting forward hypotheses, collecting explanation and testing hypotheses. The skeptical method of science plays

[1] *Webster's New World Dictionary* 1305.

[2] National Academy Of Sciences and Institute Of Medicine, Science, Evolution, and Creationism 10 (2008).

[3] Working Group On Teaching Evolution, National Academy Of Sciences, Teaching About Evolution And The Nature Of Science 27 (1998).

a very important role in scientific discovery. One of the great strengths of scientific practice is what can be called the “withering skepticism” that is usually applied to theoretical ideas, especially in physics. Scientists subject hypotheses to observational tests and reject those that fail. Good experimenters are irredeemable skeptics who thoroughly enjoy refuting the more speculative ideas of their theoretical colleagues. Through experience, they know how to reduce bias and make valid judgments that withstand the tests of time. Hypotheses that run this harrowing gauntlet and survive acquire a certain hardness or reality that mere fashions never achieve. This quality is what distinguishes science from the arts (Riordan 2003, 51). In scientific practice, the boundary between fact and conjecture is not so clear. Pierce has pointed out “when a man desires ardently to know the truth, his first effort will be to imagine what that truth can be…there is, after all, nothing but imagination that can ever supply him an inkling of truth” (Peirce 1932, 46) .

The traditional scientific viewpoint that had been almost generally accepted by contemporary scientists claims that the aim of science is to pursue and discover the truth behind nature and formulate a theory which tells us how everything is governed. There are scholars who think that science aims at careful, descriptive, and explanatory account of experience (Shreves 1919, 566-572).[4] Then, what is truth? Aristotle said “to say of what is that it is, and to say of what is not that it is not, is true” (Aristotle, 1831, 7).[5] The Enlightenment view is that truth can be discovered by using scientific methods to assess facts obtained by empirical evidence.

Traditional epistemology in western analytical philosophy has long accepted the principle that knowledge implies truth. This can be called the veracity principle, the statement that knowledge bases contain only truths: if *p* is known then *p* is true. The veracity principle is so widely accepted in epistemology that many epistemologists feel that rejecting it would be unthinkable. Nicholas Rescher wrote that holding the linkage between knowledge and truth is merely contingent “inflicts violence on the concept of knowledge as it actually operates in discourse” (Rescher 2003, 10). He describes the sentence ‘an agent knows that proposition *p* but *p* is not true’ as “senseless”. However, the veracity principle is a problem for modeling the kind of reasoning used in scientific inquiry. The reason is that knowledge in a scientific inquiry always has to be regarded as defeasible. This consequence follows from Popper’s principle of falsifiability, which tells us that any genuine scientific hypothesis should be subject to continued testing, and if it is falsified by such testing, it must be given up as part of scientific knowledge. For these reasons, Popper held that the best a successful scientific inquiry can do is to approximate the truth. Although he held that scientific knowledge is objective, he viewed scientific inquiry as a process of critical examination during a procedure that uses evidence to move forward to tentative acceptance of a scientific theory. Popper held that the procedure of conjecture and refutation begins with the formulation of a problem, goes through a process of marshaling evidence, then goes through a process of “severe critical examination” of the conjecture in a critical discussion that compares competing hypotheses (Popper 1972, 164). This inquiry procedure (Popper 1963, 312) is seen as a trial and error process that goes through degrees of improvement. At its closing stage it reaches an outcome that is provisionally acceptable as proved, once the discussion is settled by the scientific community.

[4] These scholars think that science aims at a descriptive and explanatory account of experience.

[5] Aristotle, *Metaphysics*. English translation in J. Barnes (ed.), *The Complete Works of Aristotle*, Cambridge, Mass.: Princeton University Press, 7, 1011b26–8 (1831).

Peirce also took a realistic view of scientific inquiry holding that it takes place in a finite amount of time with limited resources for collecting evidence. Hence the aim should not be that of actually reaching the truth, and thereby establishing knowledge of the kind that is fixed, but only that of a firm settling of opinion that is still open to revision. Peirce wrote (1984, 354) that the "only legitimate aim of reasoning is to ascertain what decision would be agreed upon if the question were sufficiently ventilated". Taking the opposed view, that truth should be the result of a successful inquiry, Peirce believed would "block the path of inquiry because our minds would be closed, and hence, we would never be motivated enough to inquire" (1931, 135). Clearly acceptance of the veracity axiom that knowledge requires truth is not consistent with Peirce's view of the inquiry. He warned us not to infer from the premise that we can be substantially certain about many things to the conclusion that we "perfectly know when we know" (Misak 1987, 260). It is a corollary that the iteration axiom does not work in the Peircean inquiry either. Maintaining the veracity condition is at odds with the important role that defeasible reasoning plays in the process of evaluating claims to knowledge in an inquiry.

Peirce's view of scientific knowledge and inquiry strongly appears to be inconsistent with the principle that knowledge deductively implies truth. He held the view that scientific inquiry is based on epistemological fallibilism of a kind that admits the susceptibility of scientific proof of a hypothesis to error. On this view, even the most careful scientific inquiry can produce an outcome which could change later, as further testing is carried out and new evidence comes in (Peirce 1931). Peirce wrote that many scientific findings can be accepted as "substantially certain" knowledge but he denied that this kind of scientific knowledge should be held with absolute certainty of a kind that implies truth (Peirce 1931).On his view, the motive of finding the truth is an important aim for scientific research. However, he maintained that any real scientific investigation is bound by costs and other limitations and that the kind of truth that is beyond all doubt can only be arrived at over an infinite duration of time. He also held that fixing belief too firmly by "tenacity" or "authority" is an obstruction in the way of an inquiry because it implies that no further inquiry is necessary (Cooke 2006, 34). This fallibilistic approach to the epistemology of scientific inquiry has recently led to a different way of modeling the notion of knowledge in epistemology by seeing it as a defeasible concept.

Walton proposed a defeasible conception of knowledge that is characterized by three principles (2005, 42, 59-69). The first is that knowledge is collected during a process of inquiry that admits of retraction, so that what is accepted as knowledge may later be rejected as not being part of knowledge. The second is that not only can a knowledge-base be incomplete, it can be closed off to further investigation for various reasons, including costs and other practical factors of continuing an investigation. Third, a knowledge-base can be fallible, and even if a proposition is accepted as knowledge and the inquiry is closed, it may later be reopened as new evidential facts need to be considered. On this view knowledge is defeasible, meaning that a proposition now known may later be refuted (defeated as knowledge), so that the same proposition can later properly be classified as not knowledge, by reason of the need for retraction in the process of inquiry (Walton 2005, 59-60).

Based on these epistemological principles, a bounded rationality model of scientific inquiry views an inquiry as a procedure made up of three stages: (1) an opening stage, (2) an argumentation stage in which hypotheses are put forward and tested, and (3) a closing stage where a conclusion is arrived at on whether to accept a proposition as knowledge or not (Walton 2011, 131-155). In this model, the attainment of truth is not necessary for the procedure to reasonably arrive at a conclusion on whether or not a proposition may properly be classified as knowledge. The model is based on an evidential epistemology that determines whether or not a proposition is knowledge by the weighing of the evidence for and against it during the argumentation stage. It is also a social epistemology because the process of presenting and criticizing the evidence collected at any given point in the sequence of argumentation requires an exchange of views between pro and contra sides. The degree of strength required for an argument should be determined by the standard of proof set at the opening stage of the inquiry (Prakken and Sartor, 2009). This model is the basis of the component of scientific evidence we call its internal epistemology.

Another concept closely related to scientific knowledge is common knowledge. Einstein once said that inquiry in the sciences is "nothing but a refinement of our everyday thinking" (1954, 290).[6] Popper affirmed that scientific knowledge is continuous with common sense knowledge. He said "scientific knowledge can be more easily studied than common-sense knowledge. For it is *common-sense knowledge writ large*, as it were. Its very problems are enlargements of the problems of common-sense knowledge. For example, it replaces the Humean problem of reasonable belief with the problem of the reasons for accepting or rejecting scientific theories" (Popper 1959, 18-22). Each scientist's knowledge consists of two parts: one is his or her non-professional daily life knowledge, and the other is scientific knowledge which can be obtained by scientific methods, tested and extended by systematic methods. On the one hand, science is developed from common sense and derives from questions that cannot be solved in ordinary experience and thinking. On the other hand, scientific knowledge is not only held by scientists, because once it is generalized it becomes common knowledge. Most current common sense is the result of scientific researches in the past. Although there is a relation between science and common sense, and to some extent science benefits from common sense, science is not common sense. It should be noted that the thoughts produced from science and the way of science employs them are not always intuitive. Science itself is not bound or restricted by traditional thought or common sense. The most important distinction between science and common-sense is that science is well-trained common sense. Common sense is limited objectivity because it is too closely connected with perception and actions.

In determining whether a thing offered in court belongs to real scientific knowledge or not, the key question must be asked "whether it can be (and has been) tested" (Popper 1989, 37). It is said that the scientific method is one of the ways to obtain objectivity. But the scientific method is not the warrant to objectivity because there exists no single method or rule used to identify true or reliable scientific knowledge. The scientific method doesn't *give us* objectivity, but rather, provides us with methodology to ensure we are investigating objectively. Nor is there any guarantee that all scientific claims accepted as true at any time *are* true. Almost certainly, some will eventually turn out to have been not truths (Haack 2008a, 998). John Ziman argues that we have "cast off the naïve doctrine that all science is necessarily true and that all true knowledge is necessarily scientific . . . ."(Ziman 1978, 2).To many scientists, all knowledge is fallible. Moreover, disagreement in science also shows the truth in science is relative and partial (French and Costa 2003, 84-106).[7]But disagreement about causality in science may not always be a problem for science because it can pave the way for scientific progress. For example, reasonable error-seeking resolution of scientific disagreements can stimulate progress at the "micro" level

[6] Albert Einstein, *Physics and Reality*, (1936), in Ideas and Opinions of Albert Einstein, trans. Sonja Bargmenn Crown publisher, 290 (1954).

[7] For details about inconsistency in science, see Steven French and Newton C. A. da Costa, *Science and Partial Truth: A Unitary Approach to Models and Scientific Reasoning*, Oxford University Press, 84-106 (2003).

(when disagreements with the conclusions of a study give rise to a belief that a different, presumably better, study is warranted), and at the "meta" level (when disagreement with an assessment of the causal significance of a body of evidence gives rise to a belief that a new research program is needed to reveal the underlying mechanism) (Weed 2007, 158).[8]

Scientific disagreement is reasonable, in other words, and can be resolved - or, more precisely, potentially resolved - with better studies, including improvements in the methods for interpreting the studies, the so-called methods of research synthesis (Weed 2006, 639).

2. Legal Truth and Science

As precise complex scientific methods and techniques have been applied to all fields of society, the law has followed this dominant epistemological inclination. Accurate fact-finding is important because the legitimacy of the justice system depends on it (Twining 2006, 77-78).[9] The dominant judicial test has been to admit the findings of scientific research if they have won general acceptance in the appropriate discipline. Because of this stringent test, many newer truth-revealing techniques that have not yet won admittance to the courthouse are continually storming its steps (Botein and Gordon 2002, 394).

In modern life, any human act can be transformed into a legal act. In fact-finding, the judge or jury does not have a higher competence than the ordinary person, and courts inevitably depend on expert evidence to seek truth. As a result of scientific and technological progress, the growing complexity of evidence has placed strains on a system that relies on lay people (and judges are lay people in this domain) to determine facts (Posner 1999, 1545). In the wake of stupendous scientific and technological advances made over the past fifty years, new methods of establishing facts have begun to compete with traditional ways of fact-finding in vast social spheres - including the administration of justice. An ever-increasing number of facts can now be established only by sophisticated technical instruments. And as the gulf widens between reality as perceived by our natural sensory apparatus and reality as revealed by prosthetic devices designed to discover the world beyond the reach of this apparatus, the importance of the human senses for factual inquiries has begun to decline (Damaška 1997, 153).[10] What is more, as a result of the development of modern science and especially computer technology, crime is becoming more technical and intellectual.

The epistemological value of the natural sciences is not simply the vast body of knowledge accumulated about the world and how it works, but also the way this has expanded and refined human cognitive capacities, overcome human cognitive limitations, and amplified our capacity to inquire effectively. The knowledge produced by the sciences has refined judgments of evidence by means of statistical techniques, controlled and double-blinded experiments, etc. (Haack 2007a, 300, 302). The epistemological presumption of a judicial trial is that its goal is to find the truth. However, the ultimate target of judicial trial is to solve a particular dispute. It could be said that finding the truth provides a foundation for reaching the ultimate target, but the

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[8] But at the "macro" (paradigmatic) level, where the proponents of a new ─even, revolutionary─ theory do battle with those protecting the status quo, more research may not be the key to resolution. *See* Douglas L. Weed, The Nature and Necessity of Scientific Judgment, 15 *Journal of Law and Policy*, 158 (2007).

[9] *See* William Twining, *Rethinking Evidence: Exploratory Essays* 77-78 (2006), (explaining that one of the assumptions of the rationalist tradition of evidence and proof is that "[e]stablishing the truth about particular past events in issue in a case (the facts in issue) is a necessary condition for achieving justice in adjudication; incorrect results are one form of injustice").

[10] See Mirjan R. Damaška, *Evidence Law Adrift*, Yale University Press, 143 (1997). Damaška suggests that the conventional jury courtroom will probably be confined to a very narrow category of causes and blue-ribbon juries, or special expert panels will find acceptance in many types of civil proceedings. *Id*. at 148.

achievement of the ultimate target is not solely dependent on finding out the truth. Truth is surely *relevant* to legal proceedings, for we want, not simply resolutions, but *just* resolutions; and substantial justice requires factual truth. In its efforts to arrive at factually correct verdicts, the legal system has come to rely a good deal on scientific experts (Haack 2008a, 986). Courts are eager to get the help provided by scientists in determining the factual truth. The phenomenon of science entering legal context is called the third culture (Brocknan 1996, 17). There are four basic contexts in which scientific research enters legal/political decision making: (1) trial and appellate courts in non-constitutional cases, (2) constitutional cases and especially Supreme Court decisions, (3) legislatures and (4) administrative agencies (Faigman 1999, 50).

The way the science assists courts is realized through expert witnesses testifying. In the early stages experts were members of the jury. The modern role of expert witnesses began in the 18th century. In *Folkes v.Chadd*, a famous engineer, Smeaton was allowed to give his opinion on whether an embankment had caused the silting of a harbor (*Folkes v. Chadd*).[11]

Erica Beecher-Monas suggests there are five basic requirements a judge should take into account in making a decision whether to let an expert testify. First, the judge must come to grips with the underlying theory and hypothesis. The second requirement is that the judge must examine all the available information - human studies, animal studies, cellular, and chemical structure - in concert. In this vein, it is useless – and unscientific - to expect a single study to uphold an entire explanation. Third, where there are information gaps (which are inevitable), they should be filled with scientifically justifiable default assumptions. Fourth, an inquiry into the methodology (including the laboratory or observational methods as well as statistical methodology) and whether it conforms to generally acceptable practices in the field is imperative. Finally, the judge must be able to put all this information together in such a way as to make a decision about how well the four previous steps mesh with the conclusion the expert infers (Beecher-Monas 2007, 46). As Dwyer argues, however, this approach is limited because it only attempts to separate off the most unreliable expert evidence, as opposed to finding the right answer. It does not actually tell us whether to accept seemingly reliable expert evidence (Dwyer 2008, 134).

The disagreements between scientists at trials pose many problems for fact-finders. The tribunal cannot solve scientific disagreements by the way used in science because of the differences between the two epistemological models for truth-seeking in the two fields. The legal process has to seek truth through adversarial argumentation where each side has the goal of persuading the trier following the procedural rules of the trial setting. The model here is not that of an inquiry of the scientific type that converges toward knowledge by an amassing and evaluation of evidence using scientific methods. Instead it is a persuasion social epistemology that is highly adversarial in nature, even though it is governed by procedural rules, most notably for our purposes here, rules for admissibility of evidence (discussed in section VI). The basic point is that a legal system is not well-modeled, as science is, as a kind of inquiry. It is better described as a set of rules and machinery for resolving disputes and making it possible for people to live together in some kind of order. Moreover, legal determinations are constrained not only by the desire to arrive at factually correct verdicts, but also by other, non-truth-related desiderata such as respecting values, for example fairness (justice) and protecting citizens' constitutional rights (Haack 2004, 49-50).

Most of the current literature sets up law as opposed to science and discusses the relationship between law and science by putting scientific evidence under scientific research, regardless of

[11] *Folkes v. Chadd*, 3 Dong KB 157,159, per Lord Mansfield（1782）.

the fact that scientific evidence is the product created by both science and law. Although there is a great difference between two ways of seeking truth in the courtroom and laboratory, scientific evidence first fits the internal framework of a scientific inquiry that draws conclusions that are transmitted as evidence in a legal setting where the results produced by the internal scientific inquiry are re-used to draw legal conclusions (Pardo and Allen, 2007).

As the transmission of knowledge is visualized in figure 1, scientific evidence has both an internal scientific component and an external component that bridges scientific evidence to legal evidence. The left half of figure 1 shows the internal component of the sequence of evidence. To this point, *p* is proved as a finding of scientific knowledge. The right half shows how scientific knowledge is transmitted externally (outside science). After being accepted by a scientific expert as knowledge, the proposition moves through testimony to an external audience.

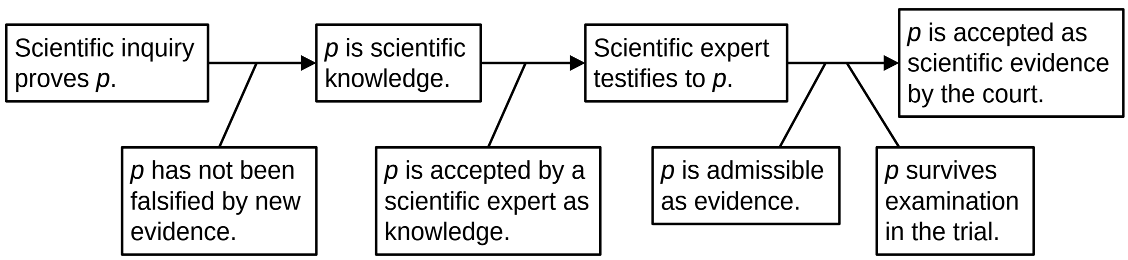

Figure 1: Transmission of Evidence from Scientific Inquiry to a Legal Setting

Generally speaking, the person who puts forward claims of knowledge in court is not regarded as a scientist or member of some academic or professional community, but an expert witness who should be trusted to carry out a specific scientific test as well as testifying to support his or her conclusion in the court. This kind of use of science is sometimes called *litigation-driven science* or *litigation-generated science* (Haack 2008b, 1054; Boden and Ozonoff 2008, 117-122; Henry and Conrad Jr 2008, 136-141). Although scientific evidence is provided by scientists, it is still used by attorneys for the proof of ultimate *probanda* in adversarial proceedings. Thus, it is more like a legal concept. The difference between the internal and the external components is that trials attempt to seek the truth about contested events, and science attempts to seek the truth about observable phenomena. When the events that are the subject of legal disputes can be determined, at least in part, by virtue of scientific discovery, we might expect the law to embrace science as a means for ensuring that legal procedures get it right (Berger and Solan 2008, 847).

B. The Epistemological Sources of Scientific Evidence

The word ‘epistemology’ is derived from the Greek words épistémé and logos, the first meaning ‘knowledge’ and the second signifying a theoretical and critical study of something (Virieux-Reymond1972, 7-8). Epistemology overlaps with the branch of cognitive science that investigates good reasoning, logic (Bishop and Trout 2005, 11). The core topics of epistemology are concerned with questions like what we know, how we know, belief, doubt and certainty. Foundationalism, coherentism and reliabilism are three versions of traditional epistemology. The basic approaches to epistemology require an account of epistemic justification (Bishop and Trout 2005, 16-17). Although epistemology has not so far provided a new method for factual inquiry, it does not mean factual inquiry does not need epistemology. For example, the U. S. Supreme Court now imposes on the federal district courts the epistemological responsibility to decide when an expert can reliably say that she "knows something" (Malone and Zwier 2001, 103-104). The relationship between epistemology and factual inquiry based on evidence is that epistemology, as a kind of basic theory and method, provides an analytic framework for factual inquiry. This paper does not focus on purely theoretical epistemology, but attempts to take into account theories in epistemology that have significant implications for the project of understanding scientific evidence.

Is scientific evidence related to epistemology? Haack remarks:

> By now, scientific evidence of just about every kind (from DNA fingerprinting to battered-wife syndrome, from studies of mice injected with potentially carcinogenic chemicals to recovered memories) plays a large and apparently ever-growing role in both criminal and civil cases. The long and tortuous history of efforts to ensure that when the legal system relies on scientific evidence it is not flimsy speculation but decent work, suggests that this interaction of science and the law raises some very tricky problems. And to judge by how often, in that long and tortuous history, explicit or implicit assumptions about the nature of scientific knowledge and the character of scientific inquiry are crucial, those problems are in part epistemological (Haack 1999, 218).

Epistemology is closely connected to science if, as scholars suggest, epistemological theory aims to uncover the normative assumptions of a branch of science (Bishop and Trout 2005, 8). Therefore, it could be said that the first epistemological source of scientific evidence is scientific epistemology. Goldman holds that one task of epistemology is to elucidate our epistemic folkways and the task of describing or elucidating folk epistemology is a scientific task, at least a task that should be informed by relevant scientific research. The second mission of epistemology, as suggested by the view above, is the formulation of a more adequate, sound, or systematic set of epistemic norms, in some way(s) transcending our naive epistemic repertoire. Goldman suggests that scientific epistemology has two branches: descriptive and normative. While descriptive scientific epistemology aims to describe our ordinary epistemic assessments, normative scientific epistemology continues the practice of making epistemic judgments, or formulating systematic principles for such judgments (Goldman 1993, 272-273).

Corbí revised Goldman's scientific epistemology as a normative scientific epistemology resting on the assumption that epistemic practices are rule-governed. Some basic features of a normative scientific epistemology include: (i) Normative scientific epistemology is bound to be continuous with our folk epistemic practice; (ii) Normative scientific epistemology not only can be, but *must* be normative; and (iii) Normative scientific epistemology needs to be scientifically informed in two ways. Scientific epistemology must, (a) take into consideration the constraints that our knowledge at a neural and a functional level impose on what can be true at an intentional level; and (b) be viewed as a discipline that, relying on several intentional sciences, focuses on epistemic practices both from an individualistic and a social perspective, while encouraging reforms for our epistemic capacities and practices (Corbí 1993, 304-305).

A recent way of reconfiguring the relation between scientific evidence and epistemology is evidentialism. Evidentialism is a philosophical approach that provides a way of analyzing knowledge using formal explanations for scientific activities as a whole. Evidentialism in epistemology emphasizes the role of evidence in knowledge, interprets knowledge explicitly as a relationship between belief and evidence, and claims the following thesis about epistemic justification: person *S* is justified in believing proposition *p* at time *t* iff *S*'s evidence for *p* at *t* supports believing *p* (Conee and Feldman 2004, 296).

The naturalistic turn in epistemology of the past thirty years provides the most appropriate theoretical framework for understanding scientific evidence. Naturalized epistemology is a new direction in the research of epistemology since the 1960's. The reason for its emergence is to solve the problems traditional epistemology encountered in answering questions about the nature of science. Its core intention is to build closer relations between natural science and epistemology, and to bridge the gap between science and philosophy. It is difficult to give a simple and clear definition for naturalized epistemology, because naturalism is not so much a system or scholarship as a kind of attitude and method. Most of the views can be traced back to the article *Epistemology Naturalized* written by Quine in 1969, based on criticizing empiricism that claims all meaning and knowledge had its origin in experience and rejecting a distinction between analytic and synthetic statements. Quine argued in his article that "Epistemology, or something like it, simply falls into place as a chapter of psychology and hence of natural science. It studied a natural phenomenon, viz., a physical human subject. This human subject had accorded a certain experimentally controlled input – certain patterns of irradiation in assorted frequencies, for instance – and in the fullness of time the subject delivers as output a description of the three-dimensional external world and its history" (Quine 1996, 82-83). We make no attempt to discuss all types of programs of naturalized epistemology here, but from either Quine's illustration or the debate between his successors and opponents, we can note one of the principal features of naturalized epistemology. This is the feature that epistemology accounts for the reasonability of scientific cognition by using the discoveries and methods of natural science not from the exterior but the interior. Most evidence scholars follow the general approach of modern naturalized epistemology, whether or not they are aware of that fact (Nance 2001, 1552). We take this observation to support our view that naturalized epistemology is a good way to understand scientific evidence epistemologically, and to provide theoretical foundations for the epistemology of scientific evidence.

However, because human cognitive behavior cannot escape from the social environment, a social epistemology that focuses on the cooperation and interaction among epistemic individuals made its advent after epistemology was naturalized. This brings out the fourth source of an epistemology of scientific evidence. Applying the perspective of veritistic social epistemology to forensic science could produce new institutional designs that would lower forensic error rates (Koppl 2008, 141). Some scholars suggest that social epistemology is simply the branch of naturalized epistemology concerned not with individual knowers but with the social processes and practices that inculcate belief. While naturalized individual epistemology depends primarily on the empirical sciences of the human cognitive apparatus, naturalized social epistemology must consider the range of empirical sciences that examine the social mechanisms of belief-inculcation (Allen and Leiter 2001, 1497). We suggest that naturalized epistemology and social epistemology are two levels of epistemology or two stages of human cognitive activities. They reflect different epistemic laws from different aspects in the same way that macro and micro economics express different economic operation rules. Naturalized epistemology provides a way for us to understand scientific evidence from the interior, and social epistemology provides us with an epistemological method to analyze the course of fact-finding based on scientific evidence from the exterior. This view of scientific evidence will be further explained in the following sections.

Ⅲ. THE STRUCTURE OF THE ESE

Scientific evidence simply means 'the evidence with respect to scientific claims and theories'. Scientific evidence, in this sense, comparable to the evidence with respect to empirical claims generally but is complex, and more dependent on instruments of observation and on the pooling of evidential resources (Haack 2007a, 57). Scientists continually observe, test, and modify the body of knowledge.

The term 'scientific evidence' as herewith defined in this article refers to a scientific conclusion which is obtained by scientific method or scientific instruments based on scientific theories and used to prove a specific scientific claim in a case in the field of application of science. In this field, scientists make use of the scientific theories derived from scientific research, analyze the evidential data scientifically in a specific case, and come up to an opinion or conclusion in the end (see Figure 2). The opinion or the conclusion is regarded as the main form of scientific evidence. According to this definition there are four characteristics of scientific evidence. First, scientific evidence is falsifiable, that is, based on defeasible reasoning concluding to acceptance of a hypothesis that is subject to retraction as new evidence comes in. Second, all scientific evidence must be based on accepted scientific principles and consistent with scientific knowledge. Third, it must relate to some specific data or objects. Fourth, during the analysis, scientific method must be put to use (NAS 2009, 15).[12] The first question that the fact-finder must answer is "do I believe this scientific evidence?" She or he has to consider two more questions in answering this question: one is "do I believe the expert who proffers the evidence?" and "is the evidence itself genuine?" In answer to the question of whether the

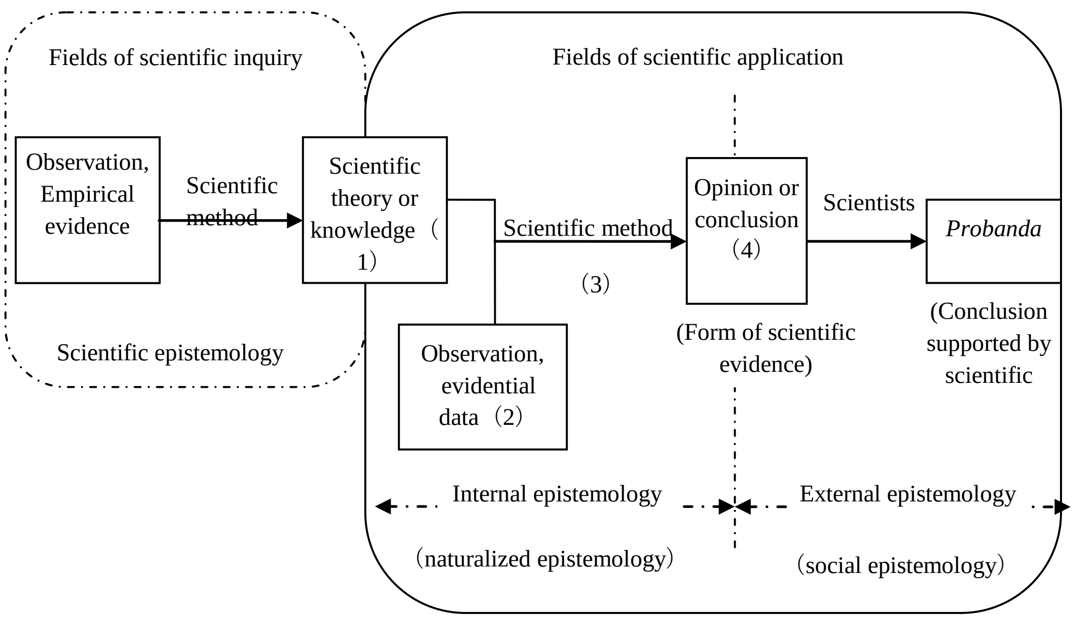

Figure 2: Structure of the ESE

evidence itself is genuine, she or he has to consider the validity, provenance and reliability of the evidence. Rather than claiming absolute truth, science approaches truth either through breakthrough discoveries or incrementally by testing theories repeatedly. Evidence is obtained through observations and measurements conducted in the natural setting or in the laboratory (NAS 2009, 81). In scientific inquiry, scientists use scientific evidence: they discover or refine scientific theories or knowledge by using empirical evidence and scientific method through observation. Thus, according to the characteristics of scientific evidence formulated above, two levels of the ESE can be explicitly sketched: internal and external epistemology.

It should be noted that internal and external epistemology of scientific evidence are very different from internalism and externalism in contemporary epistemology. Internalism about justification holds that everything necessary to provide justification for a belief is immediately available in consciousness, or that a person either does or can have a form of access to the basis for knowledge or justified belief. Externalism, by contrast, denies that one always can have this sort of access to the basis for one's knowledge and justified belief, and holds the view that there are factors other than those which are internal to the believer which can affect the justificatory status of a belief.

While internal and external epistemology of scientific evidence is classified by its structure, they work together as two essential components of knowledge. In interior epistemology, the truth of scientific evidence itself belongs to the category of scientific truth in nature. Thus the internal epistemology of scientific evidence is dependent on the properties of science itself such as scientific principles and methods. This is a naturalized way, and the difference between it and other theories of epistemology is that it is closely concerned with scientific method, or in other words, scientific method is its principal component. Scientists have to depend on scientists to recognize scientific evidence. Thus, the internal epistemology should include the cognition of scientists about scientific evidence itself. The degree to which an opinion or conclusion is warranted, at a time, for a scientist or group of people, depends on how good the scientific theory is which this person or group depended on, at that time and with respect to the method used. In exterior epistemology, on the other hand, the cognition of scientific evidence is concerned with the credibility of scientists and the conclusions or opinions about the facts in issue drawn by scientists. It represents the social dimensions of scientific evidence.

IV. THE ESE: INTERNAL COMPONENT

Naturalized epistemology seeks to uncover the relationship between observation and theory and holds that human reasoning in pursuing epistemological questions requires appealing to natural facts. Naturalized epistemology provides a philosophical foundation for the internal epistemology of scientific evidence. In answering the question of whether scientific evidence carries probative weight in court, the fact-finder has to consider the validity and reliability of evidence itself from the interior. Then what do validity and reliability mean? In *Daubert*, Justice Blackmun writes:

> We note that scientists typically distinguish between "validity" (does the principle support what it purports to show?) and "reliability" (does application of the principle produce consistent results?). Although "the difference between accuracy, validity, and reliability may be such that each is distinct from the other by no more than a hen's kick," our reference here is to evidentiary reliability—that is, trustworthiness. In a case involving scientific evidence, *evidentiary reliability* will be based upon *scientific validity* (Nance 2003, 194).

Validity is a degree of judging the significance of a measurement. It reflects the accuracy of scientific reasoning, but reliability means repeatability of result of scientific research. Although an investigation can be invalid but still reliable, it cannot be unreliable and valid. If it is unreliable then it will be invalid all the time because the measurements cannot be trusted and therefore the interpretation of the results and conclusion cannot be trusted (Gott and Duggan 2008, 3). The internal epistemology of scientific evidence aims at recognizing the validity of scientific evidence from scientific principles and methods, and distinguishing reliability from reproducibility, causality, uncertainty and error rate.

A. Scientific Validity: Scientific Principles and Methods

The word "validity" has different meanings in different disciplines, and it is very difficult to reach a stable consensus about it even within the same discipline. When scientists and philosophers cannot hold an identical view on the implication of "scientific validity", or when to use it, or how to apply it to a concrete instance of research, what rules could guide judges?

The use of expert witnesses and the necessity of judicial screening for validity of the expert's science before permitting experts to testify is one of the hotly debated areas in the bifurcation of decision-making duties between judge and jury. For scientific evidence, the question is whether the testimony has met the standards and methods of science. Even in state courts that have eschewed the *Daubert* standard in favor of the old general acceptance rule, there is increased concern with scientific validity (Beecher-Monas 2007, 18). The amended FRE enhances the obligation of the judge in assessing scientific validity. Based on the rationalist tradition in evidence scholarship and its main epistemological assumptions, Beecher-Monas discusses the question of assessing imperfect scientific studies – that is, the scientific validity of conclusions drawn from imperfect knowledge. She argues that the U.S. Supreme Court has done little to guide judges during the necessary assessment. Because most scientific studies and the conclusions culled from them are imperfect, the assessment process needs to include more than a knowledge of optimal experimental design. No study is perfect, no matter how well it has been designed. What judges and lawyers – and anyone attempting to understand the validity of scientific information - need to know is not how to design the best scientific study, but how to assess an imperfect one (Beecher-Monas 2007, 2). Scientific validity aims at answering "does the truth of evidence provide an answer to the question?" People need to examine the design of an experiment, investigation, or measurement, the way of providing a result, the explanation of a result and the conclusion when they consider validity.

One has to answer the question about the claim of truth in science with the aid of the scientific method. The scientific method refers to the body of techniques for investigating phenomena, acquiring new knowledge, or correcting and integrating previous knowledge. It is based on gathering observable, empirical and measurable evidence subject to specific principles of reasoning (Newton).[13]The scientific method presumes that events occur in consistent patterns that can be understood through careful comparison and systematic study. Knowledge is produced through a series of steps during which data is accumulated methodically, strengths and weaknesses of information are assessed, and knowledge about causal relationships is inferred (NAS 2009, 81). Simply, the scientific method is the "tool" that scientists use to find answers. The role of judge as a gatekeeper is to determine whether the testimony proffered by scientific experts is a kind of valid scientific knowledge, which *Daubert* explained as knowledge that is

[13]Isaac Newton (1687, 1713, 1726). " Rules for the study of natural philosophy", *Philosophiae Naturalis Principia Mathematica,* Third edition. The General Scholium containing the 4 rules follows Book 3, *The System of the World.* Reprinted on pages 794-796 of I. Bernard Cohen and Anne Whitman's 1999 translation, University of California PressISBN 0-520-08817-4, 974 pages.

based on scientific method (*Daubert v. Merrell Dow Pharmaceuticals, Inc*. 1993).[14]The scientific method is closely connected with scientific principle, but the scientific method emphasizes the way of obtaining scientific evidence. Generally speaking, the scientific method implies how things work in a testable hypothesis, testing whether the hypothesis is true, and expressing the measurement and data with mathematical terms. Scientific methodology is usually based on generating hypotheses and testing them to see if they can be falsified; indeed, this methodology is what distinguishes science from other fields of human inquiry (Green 1992, 643).[15] For scientists, the scientific method is the logic by which the observations are made. To scientists finding facts is only as good as the methods used to find it. Well-designed methods permit observations that lead to valid, useful, informative answers to the questions which had been framed by the researcher. For scientists, the way to figure out which one of several contradictory studies is most likely correct is to scrutinize the methodology. The methodology - the logic of research design, measures, and procedures - is the engine that generates knowledge that is scientific (Faigman et al. 2002, 117). As commonly understood, the scientific method means taking an idea about how things work, framing it in a testable hypothesis, and testing the hypothesis to see if it holds true, measured and expressed in mathematical (i.e., probabilistic) terms. But there is no monolithic scientific method, no all-inclusive set of rules that can be applied to science to determine its validity (Beecher-Monas 2007, 36). Moreover, there is no mode of inference used by all and only scientists; there is no syntactically characterizable inductive logic; and, since neither a proposition nor its negation may be warranted to any degree, degrees of warrant don't satisfy the axioms of the calculus of probabilities (Haack2003, 213). Scientists in different disciplines often use different methods; even scientists in the same discipline may use different methods. The goal of the scientific method is to ascertain whether a scientific hypothesis is a valid representation of a natural phenomenon, object, or process. Therefore, we should not exaggerate this difference within methodology because, to some extent, that there is a methodological model - such as the dialectics and abduction which has been commonly used in science - in scientific research. Moreover, epistemology also can provide a general explanation for scientific inquiry. Therefore, a scientific method consists of the collection of data through observation and experimentation, and the formulation and testing of hypotheses. We can summarize a general scientific methodology about science and discuss its general structure, developmental trend or direction. Besides the philosophical method, there are many specific methods which can be used in scientific research such as cybernetic, informative and systematic methods.

B. The Reliability of Scientific Evidence

To scientists, reliability involves the competence of applying the same method to the same thing and obtaining the same result each time. Giannelli and Imwinkelried argue that the reliability of evidence derived from a scientific theory or principle depends upon three factors: (l) the validity of the underlying theory; (2) the validity of the technique applying that theory; and (3) the proper application of the technique on a particular occasion (Giannelli and Imwinkelried 1999, 2). Systematically, there are many factors are able to account for the reliability of scientific evidence: reproducibility, causality, uncertainty and error rate.

[14]*Daubert v. Merrell Dow Pharmaceuticals, Inc*., 509 U.S. 579, 589 (1993).

[15]Michael D. Green, "Expert Witnesses and Sufficiency of Evidence in Toxic Substances Litigation: The Legacy of *Agent Orange* and Bendectin Litigation," 86 *Nw. U. L. Rev*. 643 (1992), cited in *Daubert amici curiae* brief of Nicolaas Bloembergen *et al*.

1. Reproducibility

One of the standards to judge whether an experiment is successful is to examine its reproducibility. Reproducibility in science means anyone can get the same result when measuring the same objects by using the same method under the same conditions. Popper once said: “only when certain events recur in accordance with rules of regularities, as is the case with repeatable experiments, can our observations be tested - in principle - by anyone…Indeed the scientifically significant physical effect may be defined as that which can be regularly reproduced by anyone who carries out the appropriate experiment in the way prescribed” (Popper 2002, 23-24). However, the reproducibility of the result does not mean it is right. A reliable test can be repeated under identical circumstances and yield the same results.The results may be consistently wrong, but that is an issue of validity, not reliability (Foster and Huber 1999, 111). On the other hand, if the result is irreproducible, it means there is something wrong with the method. Reproducibility in scientific experiment usually relies on a presumption that the natural law is general and perpetual. However, this presumption behind the reproducibility is a metaphysical one, because it is very difficult to establish some fully identical experiments in practice. It means that the principle of reproducibility related to reliability of scientific evidence is a weak one.

2. Causality

It is well known that there is an apparent distinction between science and law in dealing with the question of what evidence is actually concerned with assessing causality. The scope of assessment in science is broader than it in courts. While the admissibility of facts is governed by the rules of evidence in the law, science too has rules regarding the inclusion and exclusion of facts for consideration as well as rules covering which studies to include, a process that has been evolving from around the mid-1980s to the present (Weed 2008, 953).

In some cases, proof of causality is still a big challenge to scientists, because it needs judgment in determining causality, and on this point, the current science often cannot provide a certain explicit answer. What is more, the claim about causality cannot be obtained solely by calculating numbers. Determining causation necessarily requires that we think counterfactually, and draw inferences that can be tricky. If we want to know whether the emission of a chemical by a factory has led to the increase in endocrine disease in the immediate area, solid proof of causation can only come from comparing the actual world in which a population has experienced an increase in the disease, with an imaginary world in which the very same population has had precisely the same experiences except for exposure to the chemical. If the occurrence of disease does not increase in this possible world, then we can conclude that the chemical has caused the disease, since exposure to the chemical is the only difference between the real world and the possible world (Berger and Solan 2008, 849-850). There are many kinds of causality between each specific scientific evidence and fact. There may be, for example, direct, basic, auxiliary, and incentive causes in the analysis of cause of death.

The problem that underlies the indeterminacy of causation, philosopher Richard Scheines explains, is that determining causation necessarily requires that we think counterfactually, and drawing inferences from what has never occurred can be a tricky business (Scheines 2008, 959). Hill suggests the causal inference based on scientific evidence includes nine standards: strength, consistency, dose response, biological plausibility, temporality, specificity, coherence, experimentation, and analogy (Hill 1965, 295). Weed (2008) regards them as qualitative values, and suggests other important scientific values are the concepts of relevance, reliability, validity, and statistical significance. Surprisingly, Hill's criteria do not include any of the aforementioned concepts, nor do they include predictability or testability. That simple fact points out the complexity of the process. All these concepts/criteria/guidelines/values (or whatever else you want to call them) are important when making causal claims: relevance, reliability, validity, and statistical significance, predictability, testability, consistency, strength, dose response, plausibility, temporality, experimentation, specificity, coherence, and analogy (Weed 2008, 956-957). Currently, however, we can still not determine which of them is more important than others.

3. The Uncertainty of Science

Historically, in case after case, the lack of certainty in science has led to failure to act because of the demand for conclusive proof of causation. "Scientific uncertainty" usually means any area of science where there are gaps in knowledge or the lack of conclusive, cause and effect proof (Harremoës et al. 2001, 170)[16]The available scientific evidence cannot once-and-for-all determine which hypothesis is the true hypothesis among all those involved in a particular situation, and this is called *underdetermination* in science (McMullin 1995, 233, 241).[17] Whatever the cases, when it comes to individual statements of fact, the best that scientists can do is to speak in terms of probabilities and statistics (Faigman 2008, 1072). Gillies divides probabilities into logical probability, subjective probability, frequency probability and propensity probability; and logical probability and subjective probability are collectively called epistemological probability (Gillies 2000,1). Objective or physical probabilities are features of the world, and epistemological probabilities are features of belief about the world. The subjective theory treats probability as the degree of actual belief held by a particular person, whereas the logical or epistemic theory analyses probability as the degree of rational belief in a hypothesis that is justified by the evidence (Ho 2008, 113). It is concluded that epistemological probability means the extent to which a body of evidence confirms or disconfirms a hypothesis and expresses the relation between a hypothesis and the evidence which supports or undermines it. Based on standards of proof in different situations, the 11-point scale is used to express the degree of certainty or uncertainty in science analogous to the Richter scale for the strength of earthquakes. They are fundamental, rigorously proven, substantially proven, very probable, probable, more likely than not, attractive but unproven, plausible, possible, unlikely, and impossible. They allow a source of scientific information to express the subjective level of certainty or uncertainty that it associates with a particular assertion of scientific fact and can also be used to represent the range of expert opinion regarding that certainty or uncertainty (Weiss 2003, 26).

The uncertainty of scientific evidence comes from the limits of science. First, it comes from scientific principle or methods themselves. The polygraph, for example, is based on a principle that when lying, one will become nervous and have an increased pulse and need for air, and using said machine, which measures the changes in a person's body, such as blood pressure, pulse, respiration, breathing rhythms, body temperature and skin conductivity while the subject

[16] The European Environmental Agency defines three classifications of scientific uncertainty:risk (known impacts and known probabilities), uncertainty (known impacts and unknown probabilities), and ignorance (unknown impacts and unknown probabilities). See Poul Harremoës, *et al*, *Late Lessons from Early Warnings: The Precautionary Principle 1896-2000*, Copenhagen, 170 (2001).

[17]Underdetermination implies that there is always room for questioning the validity and reliability of any scientific test of any scientific hypothesis. See E. McMullin, Underdetermination, 20 J. Med. Philos. 233, 241 (1995).

is asked to answer a series of questions to detect whether he or she is lying. Apparently, this principle is very limited. Secondly, it comes from scientists themselves, because scientists are fallible human beings; and though some *are* stolid and unemotional, some are passionate—about their scientific problem, about a promising theory, about how often they are cited, and so on (Haack 2006, 50). Thirdly, it is confined by the objective conditions such as the instruments, thus, uncertainty is inevitable.

4. Error Rates

Scientific aids are fallible and imperfect: a metaphor may lead in what turns out to be a fruitless direction; an observation may turn out to be an artifact of the instrumentation; an experimental design may fail to take potential interfering factors into account (Haack2006, 51).“Error rates” are defined as proportions of cases in which the analysis led to a false conclusion (NAS 2009, 87-88). Several studies of fingerprint proficiency tests illustrate problems of error rates in forensic science tests. One study suggests a false positive rate for fingerprints of at least 2% (Peterson and Markham 1995, 994-1029). A more recent test produced a 20% rate of false positives (Grieve 1996). A third study considered a larger set of test results having an overall false positive error rate of 0.8% (Cole 2005, 1030, 1034). Although those results are very different, the accuracy or error rate in fingerprint proficiency tests has caused wide attention. The current institutional structure of forensics typically grants an individual lab a kind of monopoly on the analysis of any evidence sent to it: once a given lab has received and analyzed a body of evidence, it is unlikely that the evidence will be examined by any other lab. Periodically and randomly sending evidence to more than one lab might help break this monopoly. This is the theory of “democratic epistemics” in forensic experiments (Koppl et al. 2008, 142).

The existence of several types of potential error rates makes it absolutely critical for all involved in the analysis to be explicit and precise in the particular rate or rates referenced in a specific setting. The estimation of such error rates requires rigorously developed and conducted scientific studies. Additional factors may play a role in analyses involving human interpretation, such as the experience, training, and inherent ability of the interpreter, the protocol for conducting the interpretation, and biases from a variety of sources (NAS 2009, 89). There are many ways to calculate the error rate in science. One of the main ways is standard error that usually calculated by following formula:

$$SE = \frac{s}{\sqrt{n}}$$

Where *s* is the standard deviation of the sample, and *n* is the size (number of observations) of the sample. And the standard deviation is calculated by following formula:

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n}}$$

x is a single measurement. From these formulas, it is concluded that the error rate could be reduced by increasing the frequencies of measurement. But most of the error in a forensic test is caused by an incorrect test procedure produced by misconduct of scientists, bad condition of instruments and inappropriate materials. Before concluding that a particular enzyme-probe combination produces accurate profiles as applied to crime-scene samples at a particular laboratory, for example, courts may wish to consider studies concerning the effects of environmental conditions and contaminants on VNTR profiling as well as the laboratory's general experience and proficiency with these probes. The nature of the sample and other considerations in a particular case can affect the certainty of the profiling (Allen et al. 2002, 806).

On February 18, 2009, the National Academy of Sciences released their long anticipated report entitled "Strengthening Forensic Science in the United States: A Path Forward". The report aims at reaching the two most important goals of improving standardization and resources in forensic science. It also lists many elements that can make for errors in forensic tests. For example, it found too many scientists and other practitioners in the forensic science community lack adequate resources, sound policies, and national support. The forensic science community is plagued by fragmentation and inconsistent practices in federal, state, and local law enforcement jurisdictions and agencies. It also found that the quality of practice in forensic science disciplines varies greatly and the quality of practice often suffers because of five factors: (1) the absence of adequate training and continuing education, (2) the absence of rigorous, mandatory certification requirements for practitioners, (3) the absence of mandatory accreditation programs for laboratories, (4) failures to adhere to robust performance standards, and (5) the lack of effective oversight (NAS 2009, 5).

V. **THE ESE: EXTERNAL COMPONENT**

A. The Credibility of Expert Witness

In a trial, if the evidence in the case involves certain kinds of expertise, then the courts need experts from that field to help them to make a judgment of admissibility. For example, in criminal courts, forensic scientists are presented to explain the facts in a burglary or car theft.In civil courts, experts are often individual professionals such as medical doctors or psychologists testifying on matters such as personal injury or child welfare. As Haack mentions:

> So successful have the natural sciences been that the words "science," "scientific," and their cognates, are often used as all-purpose terms of epistemological praise, meaning, vaguely, "strong, reliable, good." This honorific usage has encouraged the idea that scientific evidence must be evidence of a peculiar, and peculiarly reliable, kind; that the sciences must owe their remarkable successes to the uniquely reliable mode of inference or procedure of inquiry that scientists use and that scientists must be unemotional and even stolid types, "objective" in a stereotypical sense. But this is all a serious misunderstanding (Haack 2006, 50).

Although it is easy for scientists to set up and maintain a good reputation for veracity and competence by virtue of professional status, it is possible that any critique of a specialist could harm his or her professional career as an expert and lower his or her academic reputation, and sometimes this injury is fatal. But this is no guarantee that all experts are truthful. We can think of no reason, however, why this problem is likely to be any greater with purported specialists than with other witnesses (Allen et al. 2002, 738). A special problem in forensic evidence is over-claiming - by expert testimony that exaggerates its own probative value (Cole 2007, 819). Moreover, there are still instances of intentional misconduct in science. For example, in West Virginia, the former head serologist of the State Police crime laboratory, Trooper Fred Zain, falsified test results in as many as 134 cases from 1979 to 1989.[18]

An important thing to realize from the point of view of the external epistemology of expert opinion evidence is that when the expert's opinion is presented as evidence in an external setting like that of a legal trial, the form of argument used is different from the kinds of arguments used in an internal scientific inquiry. The most important external form of argument is the argument from expert opinion. In the version presented below this type of argument has eight premises (Walton 2007, 134).

Competence Premise (*Ordinary Premise*): *E* is an expert in knowledge domain *D*.
Statement Premise (*Ordinary Premise*): *E* said the sentence *S**.
Interpretation Premise (*Ordinary Premise*): S is a reasonable interpretation of *S**.
Domain Premise (*Assumption*): *S* is in *D*.
Depth of Knowledge Premise (*Assumption*): The knowledge of *E* about *D* is deep enough to know about *S*.
Careful Analysis Premise (*Assumption 3*): *E*'s testimony *S** is based on his own careful analysis of evidence in this case.
Other Experts Premise (*Exception*): S is inconsistent with what other experts in *D* say.
Credibility Premise (*Exception*): *E* is not credible.
Conclusion: *S* may plausibly be taken to be true.

The defeasible nature of this form of argument is made more easily appreciable if we realize that its method of evaluation is a form of critical questioning of the kind that might take place in legal cross-examination at trial.

There are six main critical questions for argument from expert opinion, but under each of the main critical questions is a set of subquestions which has been recognized through studies of argument from expert opinion in conversational argumentation (Godden and Walton 2006, 278-279).[19]

1.*Expertise Question*: How credible is *E* as an expert source?

What is *E*'s name, job or official capacity, location, and employer?
What degrees, professional qualifications or certification by licensing agencies does *E* hold?
Can testimony of peer experts in the same field be given to support *E*'s competence?
What is *E*'s record of experience, or other indications of practiced skill in *S*?
What is *E*'s record of peer-reviewed publications or contributions to knowledge in

[18] The acts of misconduct on the part of Zain included (l) overstating the strength of results ; (2) overstating the frequency of genetic matches on individual pieces of evidence ; (3)misreporting the frequency of genetic matches on multiple pieces of evidence ; (4) reporting that multiple items [of evidence] had been tested , when only a single item had been tested ; (5) reporting inconclusive results as conclusive ; (6) repeatedly altering laboratory records ; (7) grouping results to create the erroneous impression that genetic markers had been obtained from all samples tested ; (8) failing to report conflicting results ; (9) failing to conduct or to report conducting additional testing to resolve conflicting results ; (10) implying a match with a suspect when testing supported only a match with the victim ; and (11) reporting scientifically impossible or improbable results. *See* re Investigation of the W. Va. State Police Crime Lab., Serology Div., 438 S.E.2dW. Va. 501, 503 (1993).

[19] The list below is taken from the summary in David M. Godden and Douglas Walton, Argument from Expert Opinion as Legal Evidence: Critical Questions and Admissibility Criteria of Expert Testimony in the American Legal System, *Ratio Juris*, 19, 2006, 261-286. See pp. 278-279.

S?

2.*Field Question*: Is *E* an expert in the field that *A* is in?

Is the field of expertise cited in the appeal a genuine area of knowledge, or area of technical skill that supports a claim to knowledge?

If *E* is an expert in a field closely related to the field cited in the appeal, how close is the relationship between the expertise in the two fields?

Is the issue one where expert knowledge in *any* field is directly relevant to deciding the issue?

Is the field of expertise cited an area where there are changes in techniques or rapid developments in new knowledge, and if so, is the expert up-to-date in these developments?

3.*Opinion Question*: What did *E* assert that implies *A*?

Was *E* quoted in asserting *A*? Was a reference to the source of the quote given, and can it be verified that *E* actually said *A*?

If *E* did not say *A* exactly, then what did *E* assert, and how was *A* inferred?

If the inference to A was based on more than one premise, could one premise have come from *E* and the other from a different expert?

If so, is there evidence of disagreement between what the two experts (separately) asserted?

Is what *E* asserted clear? If not, was the process of interpretation of what *E* said by the respondent who used *E*'s opinion justified?

Are other interpretations plausible?

Could important qualifications be left out?

4.*Trustworthiness Question*: Is *E* personally reliable as a source?

Is *E* biased?

Is *E* honest?

Is *E* conscientious?

5.*Consistency Question*: Is *A* consistent with what other experts assert?

Does A have general acceptance in *S*?

If not, can *E* explain why not, and give reasons why there is good evidence for *A*?

6.*Backup Evidence Question*: Is *E*'s assertion based on evidence?

What is the internal evidence the expert used herself to arrive at this opinion as her conclusion?

If there is external evidence, e.g. physical evidence reported independently of the expert, can the expert deal with this adequately?

Can it be shown that the opinion given is not one that is scientifically verifiable?

One can see by looking back at the form of the argument from expert opinion presented above that each of the premises is related to one of the six categories of critical question. There are two kinds of premises, called assumptions and exceptions. The burden of proof is different for each. If an assumption is questioned, that is enough to defeat the argument until its proponent brings forward evidence to support the premise, making the burden of proof shift to the side of the questioner. With an exception, the situation is different. When an exception is questioned, the mere asking of the question is not enough by itself to defeat the original argument from expert opinion until evidence to support the exception is brought forward. What is important to notice here is that there is a way of externally testing a claim made on the basis of expert scientific opinion that has been put forward in an external setting. This way of evaluating a claim is different from the way the same claim would be evaluated internally as a scientific hypothesis by the experts themselves in a scientific inquiry.

The argumentation-based approach works well as a method directed towards the epistemological goal of avoiding errors by process of critical questioning, in contrast to an epistemological theory that sees the goal of an inquiry as arriving at true belief. On the ESE model the procedure is seen as having a dialogue structure in which the pro arguments and con arguments are tested against each other, including critically probing procedures like cross-examination of expert testimony, that subject arguments to critical scrutiny. This procedure is designed to identify errors, including fallacies as well as weak arguments, and is therefore well adapted to the task of evaluating evidence like expert opinion testimony. The model has a dialogue structure, where burden of persuasion is set at the opening stage, and the process of testing arguments against opposed arguments is carried out during the argumentation stage. At the closing stage, a decision is made by a third-party which side had the stronger argument, based on proof standards and burdens of proof appropriate for the procedure.

In the Carneades Argumentation System, a dialogue is defined as an ordered 3-tuple <*O*, *A*, *C*> where *O* is the opening stage, *A* is the argumentation stage, and *C* is the closing stage (Gordon and Walton 2009, 5). Protocols regulate what types of speech acts are allowed as moves to be made by both parties in the sequence of argumentation. These protocols set pre-conditions and post-conditions for each type of move (Gordon, 2012). For example any party who puts forward a claim is obliged to back up that claim with some relevant evidence or else retract the claim. Commitment rules determine how propositions are accepted or rejected at each move, and how retractions can take place. It is important to note that the Carneades Argumentation System is based on acceptability of statements, burdens of proof, and proof standards (Gordon 2010, 145-156). For these reasons it fits extremely well with the ESE epistemological model. It is specifically designed for the avoidance or minimization of error, and it is acceptance-based rather than being based on the notion of true belief. It is a flexible model for dealing with defeasible reasoning in a setting where what is accepted as scientific knowledge varies with the criteria that should be used to give for it to be considered to be relevant evidence in that field (Gordon and Walton 2009, 239).

Whether a proposition is accepted as knowledge in Carneades depends on the standards of proof and the burdens of proof appropriate for the dialogue setting (Gordon, Prakken and Walton 2007, 875-896). Four standards are used in the Carneades Argumentation System (Gordon and Walton 2009, 239) in increasing order of the strictness.

- ■ Scintilla of Evidence
- There is at least one applicable argument
- ■ Preponderance of Evidence
- The scintilla of evidence standard is satisfied, and
- The maximum weight assigned to an applicable pro argument is greater than the maximum weight of an applicable con argument.
- ■ Clear and Convincing Evidence
- The preponderance of evidence standard is satisfied
- the maximum weight of applicable pro arguments exceeds some threshold α, and

- the difference between the maximum weight of the applicable pro arguments and the maximum weight of the applicable con arguments exceeds some threshold β.

■ Beyond Reasonable Doubt

- The clear and convincing evidence standard is satisfied and
- the maximum weight of the applicable con arguments is less than some threshold γ.

Notice that on this way of defining the standards of proof, the thresholds α, β and γ are left open, and are not given fixed numerical values. Whether a proposition can properly be determined to be knowledge or not depends on the evidence supporting its acceptance, weighed against the evidence supporting its rejection, at a given point in a dialogue. The Carneades Argumentation System incorporates defeasible argumentation schemes with matching sets of critical questions, for example it includes a scheme for argument from expert opinion. Having these features makes it a much better fit for the way evidence is actually processed and evaluated in a legal setting like that of a trial in the common law system.

In the process of generating scientific evidence, scientists do not undertake their epistemic activities only according to their own abstract thinking based on scientific law or principle. Inevitably, subjective factors of the scientist themselves will have some impact on testing results. These factors include their subjective prejudices, interest with the case, personality, character and the systemic and human cultural environment that a scientists lives in. In some cases, expert authentication cares more about the social interests involved and less about the scientific facts. For example, in psychiatry, it ought to be clear that, except for the diagnoses of neurological diseases (treated by neurologists), no psychiatric diagnosis is, or can be, pathology-driven. Instead, all such diagnoses are driven by non-medical, that is, economic, personal, legal, political, or social considerations and incentives. Hence, psychiatric diagnoses point neither to anatomical or physiological lesions, nor to disease-causative agents, but allude to human behaviors and human problems (Szasz 1994, 37). Scientists are only human, and usually under the constant pressures, internal and external, that can disturb the delicate incentive structure of the scientific enterprise, they may be less thorough in seeking out evidence, or less scrupulously honest in assessing its worth, than they would otherwise be (Haack 2006, 52). The goal of law enforcement actions in criminal cases is to identify those who have committed crimes and to prevent the criminal justice system from erroneously convicting the innocent. So it matters a great deal whether an expert is credited to testify about scientific evidence and whether the evidence is sufficiently reliable to merit a fact finder’s reliance on the truth that it purports to support.

B. The Belief and Justification about Scientific Evidence

1. Belief versus Knowledge: The Flaws of Traditional Definition for Knowledge

Belief and knowledge are taken to be the two basic concepts of epistemology, with justification arguably being a third one. Belief is an attitude of propositional acceptance or assent (Sayre 1997, 33), usually expressed in a form of proposition “I believe…”. When we believe something, we will tend to act according to these beliefs. In other words, belief is a kind of ground to act, but it is not a type of act or activity, only a disposition for acting. There are five leading characteristics of belief (Tuomela 2000, 122): (1) beliefs are involuntary, and are not normally subject to direct voluntary control; (2) beliefs aim at truth; (3) beliefs are evidence-related in that they are shaped by evidence for what is believed; (4) beliefs are subject to an ideal of integration or agglomeration; and (5) beliefs come in degrees.

The primary problem in epistemology is to understand exactly what is needed in order to have knowledge. In a notion derived from Plato's dialogue *Theaetetus*, philosophy has traditionally defined knowledge as justified true belief (Ayer 1956, 34). According to traditional epistemology, the relationship between belief and knowledge is that a belief is knowledge if the belief is true, and if the believer has a justification for believing it is true. One difference between *belief* and *knowledge* is that the belief includes inward acceptance of what one knows. It is possible to know that something is true but still not accept it inwardly.

There have been three modern attempts to determine whether a belief is a "true" belief. These are described as "reliability," "internal consistency," and "coherence". Philosophers have shown that not one of these attempts is sufficient to determine that a belief is reasonable (Malone and Zwier 2001, 109-117). The reason lies in the mainstream viewpoint of philosophy that classifies belief as *true belief* and *false belief*, i.e. believing a true proposition is a true belief and believing a false proposition is a false belief. We argue that both "true belief" and "false belief" are wrong concepts. Because one believes a true proposition does not mean his or her belief is true, and when one believes a false proposition does not mean his or her belief is false. There is no true or false for a belief because no matter what the proposition that one believes is true or false, there always exists a belief objectively in one's mind. But the belief might be strong or weak. In other words, belief is not of a true-or-false characteristic, rather, it is a matter of degree. The higher degree of belief we hold on an item of evidence means the more confidence we have in holding this belief in a static state, and the more difficult it is to change it to a dynamic state. Moreover, Quine discriminates between *disbelief* and *nonbelief* - between believing a sentence false and merely not believing it true. In his view, disbelief is a case of belief; to believe a sentence false is to believe the negation of the sentence true; and nonbelief is the state of suspended judgment: neither believing the sentence true nor believing it false (Quine and Ullian 1978, 12).

Only when we have beliefs can we obtain knowledge, although we may still accept things we do not believe. When knowledge cannot be obtained, belief provides a direction for further actions. Knowledge reflects the result of objective existing, belief not only rests on reflection, but also on psychology. Generally speaking, knowledge is something that has been proved by objective evidence, or can be proved by logic or other ways. The traditional definition of knowledge, which regards knowledge as justified true beliefs, was subjected to the challenge of "Gettier problem" in the 1960s (Gettier 1963, 121-123).[20] The Gettier problem challenges the philosophical tradition of defining knowledge of a proposition as justified true belief.Although most contemporary epistemologists accept Gettier's conclusion, the Gettier problem did not hit the key point of traditional knowledge theory. The main flaw in traditional knowledge theory is that the knowledge was established on the basis of a false concept - true belief. As we have mentioned above, belief is not something that possesses true-or-false characteristic, but is a matter of degree.

2. The Updating of Belief about Scientific Evidence

[20] The *Gettier problem* is considered a problem in modern epistemology issuing from counter-examples to the definition of knowledge as justified true belief. The problem owes its name to a three-page paper published in 1963, by Edmund Gettier, called *"Is Justified True Belief Knowledge?"*, in which Gettier argues that this definition is not necessarily the case. See Edmund L. Gettier, Is Justified True Belief Knowledge? 23 *Analysis*, 121-123 (1963).

People hold different beliefs in different times or contexts. Some beliefs we shall probably retain while we live, some we will abandon tomorrow in the face of adverse evidence (Quine and Ullian1978, 10). The beliefs accepted sometimes have a strong influence upon our minds, but as soon as we get new evidence, these beliefs may change. Then they tend to gain strength to a great extent, to modify our ideas and actions, and even in some instances to become very well accepted and fixed.

The traditional definition of knowledge is a kind of pure speculation and only accounts for the source of knowledge abstractly. There needs to be new epistemological methods to explain how knowledge is obtained and updated in empirical science. From an epistemological perspective, an agent holds an epistemic state or belief status at a time, but when new cognitive information is added, he or she will adjust current belief status in order to maintain a reasonable and coherent belief system. In a system of what is believed, some things stand unshakeable and some are more or less liable to shift. What stands fast does so, not because it is intrinsically obvious or convincing. It is rather held fast by what lies around it (Wittgenstein 1972, 40). If we believe some observations are consistent with our prior belief, then our belief will be enhanced, and we can say we are more certain now. On the other hand, if evidence is regarded as inconsistent with our prior belief or property, then our adherence to this property will become more uncertain.

The updating of belief is a dynamic process. Bayes' theorem is a mathematical method that can describe the dynamic updating process of belief scientifically. However, Bayes' theorem needs conditions to express updating a belief. For example, its prior probability cannot be zero. That is to say, when an item of evidence is given a prior impossibility but the evidence is actually true, Bayesian conditional probability cannot solve the problem.

After the 1970s, theories about belief update made progress in computer science, artificial intelligence, and psychology, and became a subject of controversy in these areas. One of the most influential belief update theories is AGM developed byAlchourron, Gardenfors and Makinson in 1985 (Alchourrón et al. 1985, 510-530). The AGM framework is characterized by three ways of changing the belief state: expansion, contraction and revision. Each of these operations models an idealized rational choice of beliefs in the light of new information which may or may not be consistent with current beliefs.

The AGM theory is based on certain assumptions that make it applicable to formally encoding common intuitions about the properties that a rational belief change operator should satisfy. But the results of AGM cannot be directly applied to many interesting contexts. The contraction of beliefs in the AGM is undertaken by removing inconsistent beliefs from the original belief sets. This pure contraction of beliefs seldom appears in the course of belief updates for fact-finders.

What is more, the AGM theory regards new beliefs as propositions and adds them into original belief sets, but then does not consider the change in the degree of beliefs. As a matter of fact, if the evidence that is consistent with a prior belief is added, then the prior belief will be enhanced in degree, and it will not form another new belief unless the evidence can produce a new belief for the agent. Similarly, if the evidence that is inconsistent with a prior belief is added, then the prior belief will be weakened in degree.

Thus, we suggest, during fact-finding based on scientific evidence, there are two ways of updating fact-finders' beliefs: expansion and contraction. In the external quantity of belief, on the one hand, when the new evidence which fact-finders received is consistent with the prior belief set, the belief set will be expanded, and results in the quantity of elements in belief set that will be increased. Conversely, when the new evidence which fact-finder received contradicts the prior belief set, the belief set will be contracted, and this results in the quantity of elements in belief set will be decreased. In the internal degree of belief, on the other hand, when the new evidence which the fact-finder received supports the proposition that a prior belief depends on, the belief set will be expanded, and this results in an enhanced degree of belief. Similarly, when the new evidence which the fact-finder received is against the proposition on which prior belief depends, the belief set will be contracted.

3. The Justification for Beliefs about Scientific Evidence

Because beliefs do not have the properties of "true" or "false", and reasonable beliefs are what we pursue, we can replace the concept of true belief with that of reasonable belief. Therefore, if scientific evidence supports a proposition and it is properly regarded as a kind of knowledge, the knowledge in the epistemology of scientific evidence is justified reasonable belief. *Justification* is the reason why someone (properly) holds the belief as expressed by the argumentation supporting it. There are two philosophical theories held to justify belief: foundationalism and coherentism. Foundationalism holds that all knowledge and justified beliefs rest ultimately on what are called *basic beliefs* (also commonly called foundational beliefs). Basic beliefs are beliefs that give justificatory support to other beliefs, and more derivative beliefs are based on those more basic beliefs. The basic beliefs are said to be self-justifying or self-evident, that is, they enjoy a non-inferential warrant (or justification), i.e. they are not justified *by other beliefs*. Coherentism claims there are no beliefs that are foundational or basic and every justified belief is justified in virtue of its relations to other beliefs, i.e. someone's belief is true if and only if it is *coherent* with all or most of his or her other beliefs. The main criticism facing coherentism is that there is no obvious way in which a coherent system relates to anything that might exist outside of it.

Neither foundationalism nor coherentism can solely account for the justification of an agent's belief (Haack 1994, 222).[21] The justification of a belief is based on internal considerations concerning the qualities of the function producing the belief. A belief is "justified" if and only if the input to the function is accurately represented in the output. In order to reach this justification, there are three factors that should be take into consideration: evidence, belief and standard. Evidence provides the factual foundation for belief and standard provides the judgmental root for justification. The status of justification for belief depends on an argumentation process in which the reasons for a belief are weighed evidentially against the reasons against it. How warranted an empirical claim is dependent on how well it is supported by experiential evidence and background beliefs, how reasonable of those background beliefs are, independent of the belief in question, and how much the relevant evidence the evidence includes. How well evidence supports a claim depends on how well the claim is explanatorily integrated with the evidence (Haack 1999, 224).

Reasoning from an epistemic basis, we become justified in believing some new propositions, and become justified in rejecting some propositions which we were originally justified in believing. A concrete epistemological theory will consist of an account, first, of the nature of the epistemic basis, and second, of the reasoning involved in extending and modifying

[21] Based on the flaws of both foundationalism and coherentism, Haack set up a foundherentist criteria.See Susan Haack, 1994, *Evidence and Inquiry: Towards Reconstruction in Epistemology*, Wiley-Blackwell, p 222. It is not sure whether this new theory is helpful for the justification for beliefs.

the basis (Pollock 1983, 232). Regardless whether it is direct justification or inferential justification, both use intrapersonal induction. The intrapersonal inductive method derives from a mental model theory of psychology. The idea that people rely on mental models can be traced back to Kenneth Craik's suggestion in 1943 that the mind constructs "small-scale models" of reality that it uses to anticipate events (Craik1943, 51).

Mental models comprise what may be one of the most controversial and powerful theories of human cognition yet formulated. The basic idea is that thinking consists of the construction and use of models in the mind/brain that are structurally isomorphic to the situations they represent. Thus, mental models can be constructed from perception, imagination, or the comprehension of discourse. Johnson-Laird and Byrne present a theory of conditional inference based upon the manipulation of mental models. According to them, human reasoning relies on the construction and manipulation of mental models and can be characterized as a three-step procedure. First, individuals construct a model of the state of affairs described in the premises, second they come up with a putative conclusion compatible with this model, and third they try to falsify this conclusion by constructing alternative models of the premises (Byrne and Laird 1989, 564-575).[22]

The process of interpersonal induction could be classified into three stages which are different from mental model theory in content. They are understanding, describing and validity testing. In the stage of understanding, the agent understands the implications of premises based on his or her background knowledge, and sets up an internal model for the status of things the premises described according to his or her perception. In the stage of describing, the agent manages to describe the model and points out the contents that have not been disclosed in the premises. The correctness of a conclusion relies on the quantity of mental models which the agent can set up: the more models he or she sets up, the more difficulty there is in drawing correct conclusions. In the validity testing stage, the agent will seek other possible models that can falsify the conclusion. If there is no such a model, then it proves the conclusion is valid; if there are some models of this kind, and then the agent will go back to the second stage and confirm whether there is any other true conclusion in all models established. In this stage, the agent has to find out counter-examples until he or she have searched all possible models. If the agent could not confirm whether there is any other model based on the premises, then the conclusion will be drawn in a form of uncertainty or probability. Through intrapersonal induction, the agent establishes one or more mental characterizations for the factual conclusions that will be proved by scientific evidence and use them to judge whether the conclusion is true or false.

Ⅵ. AN EPISTEMOLOGICAL CRITIQUE OF THE STANDARDS OF ADMISSIBILITY FOR SCIENTIFIC EVIDENCE

Human beings have a long intellectual history in finding facts by using scientific evidence. But the first formal admissibility standard for scientific evidence had not been established until 1923

[22] Byrne, R.M.J. & Johnson-Laird, P.N., Spatial Reasoning, 28*Journal of Memory and Language*, 564-575 (1989).Each mental model represents a possibility: people deduce that a conclusion is necessary – it must be true -- if it holds in all of their models of the premises; they infer that it is probable -- it is likely to be true -- if it holds in most of their models of the premises, and they infer that it is possible -- it may be true -- if it holds in at least one of their models of the premises.

in *Frye v. United States* (Frye v. United States 1923),[23] and the subsequent*Daubert* trilogy of cases extended this standard (The trilogy of cases began with Daubert v. Merrell Dow Pharmaceuticals, Inc., General Electric Co . v. Joiner, and Kumho Tire co. v. Carmichael).[24]

A. Questioning the Standards of Admissibility of Scientific Evidence: From Frye *to Post-*Daubert

Before the 20th century, courts did not pay attention to scientific validity in assessing the admissibility of expert evidence. A practical standard called the "commercial marketplace test" at that time was that if a person could make a living selling his knowledge in the marketplace, then presumably expertise existed (Faigman et al. 1994). In 1923, in *Frye v. United States*, the court announced that a novel scientific technique "must be sufficiently established to have gained general acceptance in the particular field in which it belongs" (Frye v. United States 1923).[25] The *Frye* test had set the first standard for admissibility of scientific evidence. However, it did not specify how a court was to find general acceptance and it was difficult to decide the definition of a relevant scientific community. For example, in forensic computing, there is no leading professional body and the boundaries of the community are hard to define (Strong 1970, 14).[26]In practice, judges usually rely on the testimony of the proffered expert about that issue. Three assumptions lie behind the *Frye* test: (1) that there is a definite point at which scientific claims or techniques cease to be "experimental" and become "demonstrable", (2) that a claim or technique has not achieved this "demonstrable" status unless it is generally accepted in the relevant community, and (3) that only "demonstrable" claims and techniques should be admitted. Haack argues that these epistemological assumptions behind the *Frye* test are quite crude, because the *Frye* test had the judge rely obliquely on the verdict of the appropriate scientific subcommunity (Haack 1999, 28).

FRE displaced the *Frye* test in1975. Even so, in the 70 years since its formulation in the *Frye* case, the "general acceptance" test has been the dominant standard for determining the admissibility of novel scientific evidence at trial. Until 1993, in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, the Supreme Court explained that in order for expert testimony to be

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[23]*Frye v. United States,*293 F. 1014 (D.C. Cir. 1923).

[24] The trilogy of cases began with *Daubert v. Merrell Dow Pharmaceuticals, Inc*., *General Electric Co .v. Joiner*, and *Kumho Tire co. v. Carmichael*.

[25]The *Frye* case involved a murder trial in which the defendant sought to demonstrate his innocence through the admission of a lie detector test that measured systolic blood pressure. The court rejected the evidence, stating:

> Just when a scientific principle or discovery crosses the line between the experimental and demonstrable stages is difficult to define. Somewhere in this twilight zone the evidential force of the principle must be recognized, and while courts will go a long way in admitting expert testimony deduced from a well-recognized scientific principle or discovery, the thing from which the deduction is made must be sufficiently established to have gained general acceptance in the particular field in which it belongs. (See *Frye v. United States*, 54 App. D.C. 46, 293 F. 1014 (1923)).

[26]Over time, a number of courts and commentators found the "general acceptance" test seriously wanting. SeeJ.W. Strong, Questions Affecting The Admissibility Of Scientific Evidence. *U.ILL. L.F*. 1, 14 (1970) ("The *Frye* standard, however, tends to obscure these proper considerations by asserting an undefinable general acceptance as the principal if not sole determinative factor."); P.C. Giannelli, The Admissibility of Novel Scientific Evidence: *Frye V. United States*, A Half-Century Later. 80 *COLUM.L.REV*., 1197, 1207-1208 (1980) ("[T]he problems *Frye* has engendered–the difficulties in applying the test and the anomolous results it creates–so far outweigh [its] advantages that the argument for adopting a different test has become overwhelming."); M. McCormick, Scientific Evidence: Defining A New Approach To Admissibility. 67 *IOWAL.REV*., 879, 915 (1982) (*Frye*'s "main drawbacks are its inflexibility, confusion of issues, and superfluity.").

considered reliable, the expert must have derived his or her conclusions from the scientific method. In explaining this evidentiary standard, the *Daubert* Court pointed to five factors that might be considered by a trial judge: (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 (Daubert v. Merrell Dow Pharmaceuticals, Inc. 1999).[27] A critical difference between *Daubert* and *Frye* is the shift from proxy criteria for assessing scientific evidence to a direct judicial inquiry into scientific validity (Black et al. 1994, 715). *Fry*e, on its face, does not ask the judge to decide whether the evidence is reliable, but rather, whether the expert community deems it reliable, while *Daubert* requires the judge to personally assess the reliability of the evidence (Mnookin2007, 764). *Daubert* is not supposed to be a methodological handbook for good science; it is supposed to set out a standard for good adjudication (Leiter 1997, 817). Giannelli summarized five important effects from *Daubert*. First, some federal courts have read the *Daubert* trilogy as inviting a "reexamination even of 'generally accepted' venerable, technical fields". Next, *Daubert* closed a major loophole in the *Frye* rule; many *Frye* courts recognize an exception for non-novel evidence, which exempts certain techniques from the general acceptance requirement. *Daubert's* effect on the Frye test has also been noteworthy. *Daubert* forced state courts to reexamine their admissibility standards for scientific evidence. *Daubert's* effect on the third approach to scientific evidence may have been the most profound one. Finally, the 2000 amendment to Federal Rule of Evidence 702 can be traced to *Daubert* (Giannelli 2003, 7-12).[28]However, the "standard of reliability" set up in *Daubert* was subjected to many critiques.

As far as philosophical foundations are concerned, firstly, *Daubert* equates scientific with validity and reliability, and confuses Karl Popper's and Carl Hempel's incompatible philosophies of science by running "reliable" together with "scientific," and "genuinely scientific" with "conducted in accordance with the scientific method" (Haack 2008a, 989). The epistemological problems became acute when, with *Daubert*, the Supreme Court interpreted the Federal Rules as requiring the trial judge to make determinations about reliability, and to make an appraisal of scientific methodology, not by appeal to the scientific community, but on his own (Haack2007a, 251). Haack thinks that the epistemological assumptions on which the *Daubert* ruling rests are badly confused. Unlike the *Frye* test, the Federal Rules as interpreted in *Daubert* require the trial judge to make determinations about scientific methodology on his own. But what the *Daubert*

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[27]*Daubert v. Merrell Dow Pharmaceuticals, Inc.*509 U.S. 592-94 (1993).

[28] Paul C. Giannelli, Admissibility Of Scientific Evidence, 28 *Oklahoma CityUniversity Law Review*, 7-12 (2003). The commentary accompanying the revised rule recites the *"Daubert* factors" and then goes on to explain that: Courts both before and after *Daubert* have found other factors relevant in determining whether expert testimony is sufficiently reliable to be considered by the trier of fact. These factors include: (1) whether experts are proposing to testify about matters growing naturally and directly out of research they have conducted independent of the litigation, or whether they have developed their opinions expressly for purposes of testifying; (2) Whether the expert has unjustifiably extrapolated from an accepted premise to an unfounded conclusion; (3) Whether the expert has adequately accounted for obvious alternative explanations; (4) Whether the expert is being as careful as he would be in his regular professional work outside his paid litigation consulting; and (5) Whether the field of expertise claimed by the expert is known to reach reliable results for the type of opinion the expert would give. …The amendment [to Rule 702] does not distinguish between scientific and other forms of expert testimony. The trial court's gatekeeping function applies to testimony by any expert. While the relevant factors for determining reliability will vary from expertise to expertise, the amendment rejects the premise that an expert's testimony should be treated more permissively simply because it is outside the realm of science. See FED. R. EVID. 702 Advisory Committee'S Note (2000 Amendments).

Court has to offer by way of advice about how to make such determinations is difficult to implement (Haack 1999, 231). It could be said that since *Daubert*, trial judges must now weigh a complex set of philosophical and methodological factors in deciding upon the admissibility of proffered scientific evidence, rather than falling back on the simple proxy of "general acceptance" (Leiter 1997, 804).

Applying the *Daubert* rule, secondly, the judges demanded a level of certainty that was virtually impossible to provide. It is not so easy to apply the *Daubert* standard in practice because it set up an unrealistic requirement in epistemic competence for assessing scientific evidence. Blackmun explicitly stated that "arguably, there are no certainties", and Judge Kozinski wrote "*Daubert* puts federal judges in an uncomfortable position".[29] Academics, practitioners, and trial judges have complained that the standard is unclear, difficult to interpret, leads to inconsistent results, and requires hearings that cost time and money, or are too confusing to the jury (Browne et al. 1998, 5). For example, Mason critiqued the current approaches to the scientific evidence problem, particularly the standard set in the *Daubert* case. He argued that any admissibility standard of scientific evidence ought to consider the potential of a piece of evidence to acquaint the trier of fact with the truth, but the *Daubert* standard is inappropriate because it does not aid in the search for truth, and thus justice is not served. A scientific admissibility standard ought to take into account truth, knowledge and justice, but the uncertainty model contained in the *Daubert* standard only takes into account a particular *theory* of knowledge, making *Daubert's* shortcomings call for an alternative (Mason 2001, 900, 902). Mason concluded that there is no solution, *per se*, to the scientific evidence problem because the presumption that scientific evidence might be "more true" or "less true" is erroneous (Mason 2001, 888). The Supreme Court's *Daubert* decision or, more appropriately, some judges' interpretation of *Daubert*, encourages an anti-scientific method for evaluating scientific evidence requiring that each piece of scientific data be evaluated independently for relevance and reliability (Michaels 2005, 40). Some scholars, for example Friedman, argue that reliability is an inappropriate, misleading standard for testing the admissibility of expert evidence. It does not reflect the way we should think about admissibility issues, and it ought to be discarded, In his opinion, the model created by *Daubert v. Merrell Dow Pharm, Inc.* and *General Electric Co. v. Joiner*, and extended by *Kumho Tire co. v. Carmichael*, in which trial courts, reviewed under an abuse of discretion standard, act as gatekeepers to prevent jurors from being bamboozled by unreliable evidence, is not a useful one (Friedman 2003, 1047-1048). What needs to be taken into account are the characteristics of scientific evidence that make it different from other kinds of evidence.

In *Kumho Tire co. v. Carmichael*, the Supreme Court shifted the question "whether an expert testimony is scientific" to "whether an expert testimony is reliable" (*Kumho Tire co. v. Carmichael* 1999).[30] In the post-*Daubert* era, as the new FRE 702 is written, the key term is "knowledge", not "scientific". Therefore, the judge is required not only to make a legal judgment, but one of relevance and reliability of scientific evidence as well. Incorporating the new Federal Rule of Evidence 702, the three-fold epistemological criterion of sufficiency, reliability, and reliable applicability to the case at hand seems to require a federal district judge to perform a logician's analysis on each expert's testimony (Malone and Zwier 2001, 103-104). According to Malone &Zwier, the Supreme Court's epistemological confusion is a natural result of the ongoing debate between philosophy and science (Malone and Zwier 2001, 107).

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[29] *Daubert v. Merrell Dow Pharm, Inc.*, 43 F.3d 1311, 1315 (9th Cir.)

[30] *Kumho Tire co. v. Carmichael*.526 U.S. 137 (1999).

B. The Standard of Reliability as an Evidence Rule

There are three key concepts concerned with the evaluation of scientific evidence in the legal context: admissibility, reliability, and validity. There were three important developments in the 1990s that affected the admissibility of scientific evidence. The first was the advent of DNA profiling and the "wars" that surrounded admissibility. The second involved so-called "scientific evidence abuse cases". The third development is the *Daubert* trilogy: the Supreme Court's decisions in *Daubert v. Merrell Dow Pharmaceuticals, Inc*., *General Electric Co. v. Joiner*, and *Kumho Tire Co. v. Carmichael*. *Daubert* and its progeny have dramatically altered the admissibility issue (Giannelli2003, 1-3). FRE 702 sets up a standard of reliability for scientific evidence, it says:

> If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise, if (1) the testimony is based upon sufficient facts or data, (2) the testimony is the product of reliable principles and methods, and (3) the witness has applied the principles and methods reliably to the facts of the case.[31]

The reliability of scientific evidence, however, is not free of difficulties, for several reasons.

First, the limits of peer review and publication make it is very difficult to apply in a trial. Peer review is described as: "an organized method for evaluating scientific work which is used by scientists to certify the correctness of procedures, establish the plausibility of results, and allocate scarce resources (such as journal space, research funds, recognition, and special honor)" (Chubin and Hackett 1990, 2). Peer review seems to operate more effectively where scientists share backgrounds and theoretical commitments. Where there are substantial differences of approach, or in adversarial contexts, peer review may become a less reliable mechanism (Edmond 2000, 231). It is impossible to ask a forensic test result to be peer-reviewed because of the limited time in litigation. Publication (which is but one element of peer review) is not a *sine qua non* of admissibility; it does not necessarily correlate with reliability (Jasanoff1990, 61-76). Haack argues that Justice Blackmun's observation about peer review and publication in *Daubert* is neither necessary nor sufficient for evidentiary reliability. Nor is his advice to courts that peer-reviewed publication may be relevant, but is not a dispositive consideration in determining admissibility of much practical help (Haack2007b, 791-792).[32]With more and more papers submitted to more and more journals, the quality of reviewers and the time and attention they can give to their task is likely to decline. And as pressures on journals and their staffs increase, the hope of prestige and profit causes further distortions. Some journals suspend the peer-review process when they publish symposia sponsored by pharmaceutical companies. Some reap large sums from the sale of large numbers of reprints to the companies concerned. Some put pressure on authors to cite other papers in the same journal, thus raising its "impact factor" and boosting library orders (Haack2007b, 801-802). In short, peer review is expensive, slow, prone to bias, open to abuse, possibly anti-innovatory, and unable to detect fraud (Smith 1997, 759). Work that has passed pre-publication peer review is no guarantee that it is not flawed or even fraudulent, and the fact that work has been rejected by reviewers is no guarantee that it is not an important advance (Haack2007b, 808).

Second, there is a matter of "error rates". How precisely must we know the error rate of a particular technique? And what does one make of a technique with a known, very high error

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[31]FED. R. EVID, 702 (2009).

[32] But she thinks that surviving the long-term process of review by the scientific community is a much better indicator of scientific validity. See Susan Haack, Peer Review and Publication: Lessons for Lawyers, 36 *Stetson L. Rev.*, 791-792 (2007).

rate? The rate may be known with some precision, but that does not mean the technique gets a "yes" answer to this component of the reliability inquiry (Nance 2003, 200). The error rates are very difficult to calculate in deciding admissibility of scientific evidence, so it is unrealistic to regard it as one of the conditions of admissibility of scientific evidence. And the error rates which people can accept depend on the mission or the questions that must be answered. It should be noted that error rate in scientific research is only a crude estimate.

Third, gaining general acceptance in the particular field in which it belongs can be problematic. The *Daubert* standard equates the question of whether expert testimony is reliable with the question of whether it is genuinely scientific. That something has been generally accepted in a field does not mean it is scientific. What is more, many scientific techniques do not fall within the domain of a single academic discipline or professional field, especially in the current interdisciplinary era. For example, DNA involves several disciplines such as molecular biology, genetics, environmental biology, physical anthropology, evolutionary biology, population genetics, and statistics. General acceptance of RFLP (DNA) does not mean that PCR (DNA), or even a particular type of PCR such as DQalpha, is necessarily admissible.

Frye, *Daubert* or *Kumho Tire* had attempted to set a standard for the admissibility of scientific evidence in legal proceedings. Law manages to establish a standard of admissibility for scientific evidence that is different from the lay witnesses. It mainly subjects the expert witness to different requirements from lay witness. But expert testimony gets special treatment in *Daubert* with regard to the distinction between sufficiency and admissibility, and often trial courts seem to make a sufficiency determination in the guise of an admissibility determination (Allen et al. 2002, 772). On the one hand, what we should pay attention to is that the so-called *Frye* and *Daubert* rules both are made through excluding scientific evidence. This means that neither *Frye* nor *Daubert* provided a direct source for the admissibility of scientific evidence. As a kind of evidence rule, on the other hand, the *Daubert* standard was made for civil cases, and whether it is appropriate to criminal cases is still in question (Beecher-Monas 2009, 1).[33] Commentators have noted that on the whole, at least in civil cases, *Daubert* has made it harder, not easier, to get scientific testimony admitted ().[34]*Kumho Tire* extended *Daubert* to techniques

[33]Erica Beecher-Monas remarks that over the past decade, courts throughout the common law system have taken an increasingly antithetical approach to expert testimony. In civil cases, and in criminal DNA identification cases, courts appear to be actively engaged in scrutinizing the scientific testimony that comes before them. Defense attorneys appear to have little difficulty in challenging questionable scientific testimony. Research scientists are brought into the discourse as experts for the parties or the court. Courts are articulating the bases for their admissibility decisions, and these decisions are being reviewed on appeal. In the criminal cases, however, where criminal identification procedures other than DNA are concerned, each of the participants in the legal process has failed. Prosecutors repeatedly present experts whose testimony they have reason to know is (at best) dubious. Defense attorneys fail to bring challenges to the scientific validity of even patently flawed expert testimony. Courts, when challenges do arise, fail to engage in serious gatekeeping. And reviewing courts refuse to find shoddy gatekeeping to be an abuse of discretion. The consequence of this antithetical approach to admissibility, is that the rational search for truth, in which the adversary system is supposedly engaged, is taken seriously only in civil cases. While the civil courts are busy minutely scrutinizing scientific studies proffered as the basis for expert testimony, the criminal courts are admitting into evidence testimony (again, with the exception of DNA) for which those studies have never been done. *See* Erica Beecher-Monas, Paradoxical Validity Determinations: A Decade of Antithetical Approaches to Admissibility of Expert Evidence, 6 (2) *International Commentary on Evidence*, Article 2 (2009).

[34]*See, e.g.*, Lisa Heinzerling, *Doubting* Daubert, 14 *J. L. & POL'Y*, 65, 68 (2006).The report on the forensic sciences in the United States released by the National Academy of Sciences On February 18, 2009, has noted the situation is very different in civil cases from criminal cases. The party who loses before the trial court in a nonfrivolous civil case always has the right and incentive to appeal to contest the admission or exclusion of expert testimony. In addition, plaintiffs and defendants, equally, are more likely to have access to expert witnesses in civil cases, whereas prosecutors usually have an advantage over most defendants in offering expert testimony in criminal cases. And, ironically, the appellate courts appear to be more willing to

and other specialized knowledge; it is very difficult for the *Daubert* standard to provide a useful guide for deciding all evidence's admissibility in fact-finding. Although FRE 702 requires admissible expert testimony must be based upon sufficient facts or data, the product of reliable principles must have applied reliably to the facts of the case, and we should note that the standard of admissibility of scientific evidence does not provide a new way for seeking truth (Allen et al. 2002, 759). For this reason, Edmond suggests federal judges should begin to think about an exit strategy:

> They should be systematically *downsizing Daubert*. They should start winding back the Daubert era by rejecting simplistic models of science and revising their anxiety about plaintiffs and civil juries. They should also begin to apply the Daubert criteria more flexibly and take a more expansive view of *science for litigation* that extends to the state and corporate-sponsored science. They should also reflect on the type of litigation and the rights, interests and responsibilities at stake. Judges should also consider the kinds of evidence and the resources available to the parties (Edmond 2007, 923).

Friedman has even taken the position that *Daubert's* admissibility requirement is not necessary at all, and that expert evidence should simply be treated like all other evidence (Friedman 2003, 1047). This remark indicates that an epistemological reconstruction of admissibility could be of great help for fact-finders to admit and assess scientific evidence.

C. An Epistemological Reconstruction for Admissibility of Scientific Evidence

As a point of departure, roughly, expert testimony can be divided into scientific expert testimony and nonscientific expert testimony. Although ultimately all types of expert knowledge are based on inferences from underlying experience, the epistemology of nonscientific expert testimony knowledge is different from that of scientific propositions. A promising epistemological approach - scrutinizing the manner in which nonscientific expert information is generated to develop admissibility standards ensuring the reliability of nonscientific expert testimony - has been formulated in the article "*The Next Step After Daubert: Developing a Similarly Epistemological Approach to Ensuring the Reliability of Nonscientific Expert Testimony*" (Imwinkelried 1994, 2271). Although the *Daubert* Court employed epistemological analysis to develop standards of validating scientific testimony, it is necessary to reconstruct the epistemological admissibility of scientific evidence based on the above discussion.

It is noteworthy that distinguishing admissible from inadmissible scientific evidence is a different problem from distinguishing real science from pseudoscience. First, as noted above, not all expert evidence is necessarily science. It is well established that legitimate experts can be technicians or others with "specialized knowledge". Second, philosophers of science tend to think about knowledge claims in larger units of analysis than do lawyers and judges.

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second-guess trial court judgments on the admissibility of purported scientific evidence in civil cases than in criminal cases. *See*the NationalAcademy of Sciences, "Strengthening Forensic Science in the United States: A Path Forward, the NationalAcademy Press, 71 (2009). *See* also D.L. Faigman et al., 2007-2008. *Modern Scientific Evidence: The Law and Science of Expert Testimony*. Eagan, MN: Thomson/West,, § 1:35, p. 105 (discussing studies suggesting that courts "employ *Daubert*more lackadaisically in criminal trials—especially in regard to prosecution evidence—than in civil cases—especially in regard to plaintiff evidence"); Risinger, op. cit., *supra* note 52, p. 100 ("The system shipwreck I fear is that in ten years we will find that civil cases are subject to strict standards of expertise quality control, while criminal cases are not. The result would be that the pocketbooks of civil defendants would be protected from plaintiffs' claims by exclusion of undependable expert testimony, but that criminal defendants would not be protected from conviction based on similarly undependable expert testimony. Such a result would seem particularly unacceptable given the law's claim that inaccurate criminal convictions are substantially worse than inaccurate civil judgments, reflected in the different applicable standards of proof.").

Admissibility determinations tend to focus on smaller units of analysis. Philosophers are generally thinking about how one can defend the knowledge claims of a broad approach to knowing the world, whereas the "task at hand" of judges is thinking about how one can defend one very specific knowledge claim (Risinger 2000, 767). Finally, admissibility is fundamentally a policy determination, whereas Popper was concerned with defining "science" as a particular, and special, form of inquiry (Cole 2007, 809-810). There is one other factor to take into account in deciding how receptive the law should be to specialized evidence: a judge's proclivity to exclude unusual types of specialized evidence can prevent litigants from taking advantage of innovative, highly probative information and, as a result, detract from the search for truth (Allen et al. 2002, 738).

The courts have two broad choices in dealing with expert evidence. One option is to allow all expert evidence into court and rely on that great truth-producing engine, cross-examination, to sort good evidence from bad. The other is to seek to "manage" expert evidence in some way - that is, to adopt some sort of admissibility procedure, mechanism, threshold, etc., by which the fact-finder is not permitted to hear some expert evidence (Cole 2007, 805). The real problem in trial is that too many trial judges idealize science. Justice Blackmun asserts: "Of course, it would be unreasonable to conclude that the subject of scientific testimony must be 'known' to a certainty; arguably, there are no certainties in science" (*Daubert vs. Merrell Dow Pharmaceuticals*, 1993).[35] The paradoxical consequence of idealizing science is that those judges are either too harsh or too generous toward scientific experts in the courtroom. By "too harsh", we mean that such a trial judge sometimes expects too much from science, which after all is not a perfect enterprise, even when the relevant areas of science are relatively solid and respectable. The scientific issues in litigation tend to turn not on firmly-established, well-warranted core scientific principles, but on still-controversial scientific issues where there remains room for reasonable disagreement even among competent, honest scientists in the field (Haack 2008a, 1001). By "too generous", we mean that such a trial judge sometimes idolizes scientific authority without critically evaluating its limitations. In either case, the best science for a particular lawsuit can be missed (Caudill and Larue 2006, 3-4). In other words, not only does the legal system quite often seek scientific answers when no warranted answers are available, it also quite often fails to adapt, or adapts painfully slowly, as new scientific answers become available (Haack 2008a, 1004).

It seems that there is a wide gap between standards of admissibility and epistemology. Epistemology, however, the study of the nature and grounds of knowledge, can answer the question of why we need a gatekeeper. From an epistemic vantage point, the question of whether we need judges to act as gatekeepers depends on whether gatekeeping actually promotes better, that is, more accurate and more rational, decision making in the context of a particular social practice such as legal proceedings (Beecher-Monas 2007, 14). The adversarial character of the legal system may mean that even solid scientific information gets distorted. It may suppress or sequester relevant data. It may demand scientific answers when none is yet well-warranted (Haack 2008a, 1000). Thus we have admissibility standards so that those proffered witnesses who choose to don the mantle of "expert" may be held to a higher standard than the mere "relevance" required of ordinary witnesses. Under *Daubert*, "relevance" is neatly paired with an equally succinct R concept: "reliability" (Cole 2007, 805).

Paternalism in any domain of legal regulation supposes that rules should substitute the rulemaker's judgment about what is best for the agents'own judgments. Epistemic paternalism

[35] *Daubert vs. Merrell Dow Pharmaceuticals*, 1993, p. 2795.

substitutes the rulemaker's judgments about what is epistemically best for agents own judgment. Assuming that the primary epistemic value is truth, epistemic paternalism entails designing rules of evidence that are epistemically best for jurors, i.e. that lead them to form true beliefs about disputed matters of facts (Leiter 1997, 803, 814).

Given the limited amount of relevant empirical scientific evidence that is typically available, however, deciding in a legal setting whether such claims are actually true or false can be extremely difficult. As courts have no choice but to decide such matters, they need a rational process by which to synthesize the evidence for or against causal claims - both with respect to our best scientific guess about the truth of the claim and with respect to the scientific uncertainty about such a guess (Scheines 2008, 960). Scientific investigation is not an effort to reach consensus; it is, rather, an effort to answer the questions at issue. Consensus is a byproduct that arises when enough members of the relevant scientific community come to see the evidence as warranting a claim or a theory (Haack 2008a, 997). But once scientific evidence enters the court, consensus becomes essential.

The admissibility of scientific evidence is not free of difficulties as a rule, but an epistemological standard for admissibility is available. Based on the structural analysis of ESE above, we can set the standard of admissibility of scientific evidence now from an epistemological perspective as follows. The admissibility of scientific evidence should depend first on its internal reliability based on scientific validity. Second, it should depend on the justification for beliefs about scientific evidence. Under this condition, evidence law can do more than admitting scientific evidence in trials. For example, some potential solutions to admissibility standards of scientific evidence are suggested, including using science courts, letting the jury hear all of the scientific evidence proffered, or asking trial judges to learn the relevant science.

A new approach put forward by Mason is that judges should consider three factors: (1) relevance of the evidence; (2) the evidence's ability to assist the trier of fact in a determination of legal truth; (3) the judges' overall confidence in the science (Mason 2001, 905). Mason's idea is to let in all evidence that might help the triers of fact in their quest for truth, and the judge's role in determining the admissibility of scientific evidence is only to make sure it is relevant and and legitimate. This approach respects science as a method of inquiry because it puts more evidence in front of the finders of fact and lets them come to a conclusion regarding the evidence. However, as Mason comments himself, this type of approach makes the gatekeepers' role easier in some respects and more difficult in others. They may have to learn disciplines they have never been exposed to before or employ the help of special tutors to perform the task (Mason 2001, 906).

Haack argues that legal efforts to winnow decent scientific evidence from the chaff have often been based on false assumptions about science and how it works. It doesn't follow, unfortunately, that if we had a better understanding of science, all problems could be easily resolved. She remarks:

> A better understanding of scientific evidence and inquiry will reveal why it has proven so difficult to find a legal form of words that will ensure that only decent scientific evidence is admitted, or a simple way to delegate some of the responsibility to scientists themselves; but rather than suggesting any easy solutions it accentuates the need to think hard and carefully about what goals we should be trying to achieve, and what kinds of imperfection in achieving them we are more willing, and what we are less willing, to tolerate (Haack 1999, 219).

An empirical study, however, drew a different conclusion. A survey of 400 judges and a mock jury mtDNA study showed that their educational attainment and background in science and math were associated with better comprehension of the scientific evidence (Hans 2008, 44). It is really difficult to judge the worth of scientific evidence without substantive knowledge of the appropriate field, but understanding scientific evidence in the proceedings of fact-finding does not necessarily require judges or jury to learn scientific knowledge like scientists, but to know it epistemologically, so to speak. Judicial decision-making is subject to relevant standard and objective facts, but finally depends on human judgment. Although the justification for beliefs about scientific evidence rests on its reliability and expert's credibility, evidence law is playing an important role during the course of justification because discovering reliability and credibility relies on legal techniques such as cross-examination. After an item of scientific evidence is admitted, the next job is to judge its worth for proving facts at issue according to evidence law.

At this time, expert testimony is subject to the rules of evidence law. And the validity of a scientific principle and the validity of the technique applying that principle may be established through judicial notice, legislative recognition, stipulation, or the presentation of evidence - including expert testimony (Giannelli 2003, 4). The judge does not have to decide whether a given scientific hypothesis is actually correct. Rather, what the gatekeeper must determine is whether there are good grounds for the expert's testimony. Once this determination has been made, it remains the jury's province to decide which set of battling experts has the most persuasive argument (Beecher-Monas 2007, 19). If deciding a case actually is reducible to a choice between the hunches of experts that cannot be further explained, the case most likely does not belong in the courts (Allen et al. 2002, 766). Truth is hard to come by, but both the legal and scientific communities have evolved principles and procedures to minimize bias and integrate declarative truth with scientific and judicial realism (Glucksberg 2008, 1113). If there were something that needs to be reformed, it should be law, not science.

Ⅶ. CONCLUSION

There are great differences between the quest for truth in the courtroom and the quest for truth in the laboratory. Fact-finding based on scientific evidence integrates both models of truth-seeking. Scientific epistemology, evidential epistemology, naturalized epistemology and social epistemology provide theoretical resources for the ESE, which we present as a methodology for understanding and using scientific evidence. We have argued that, in line with our epistemological theory, the function of scientific evidence in truth-finding needs to be examined from transmission of evidence from the internal framework to the external one. Internal epistemology depends on the properties of scientific evidence itself and aims at proving the validity of scientific evidence using scientific principles and methods, assessing its reliability based on the factors of reproducibility, causes, uncertainty and error rate. External epistemology is constructed by factors outside scientific evidence itself, including the credibility of scientific experts, and the beliefs and justification for beliefs about scientific evidence by agents.

An important tool for the assessment of scientific evidence in external epistemology is the logical argumentation scheme for argument from expert opinion, along with its accompanying set of critical questions that can be represented as additional assumptions embedded in the form of an argument. This tool can be used to judge whether an argument from expert opinion is acceptable or not, based on critical questions that can be employed to probe into the weak points of the testimony. In this external setting, belief is not a true-or-false characteristic but a matter of degree and fixation of acceptance depending on doubts raised by critical questioning when the evidence is critically examined (Walton 2006, 745-777). Traditional epistemology established knowledge on the basis of a false concept - true belief. On our theory, scientific evidence should be based on a process of justifying the agent's reasonable acceptance of a hypothesis in an inquiry that ends in proof. We have shown in section V how this procedure can be modeled using the Carneades Argumentation System. Any proposition that cannot be proved in an inquiry to an appropriate standard of proof following this kind of epistemological procedure is not acceptable as knowledge.

This article concludes what the basic theory and method of the ESE should have from internal and external components. The internal components are comprised of the properties of scientific evidence itself, involving scientific validity (scientific principles and method) and reliability (reproducibility, causes, uncertainty and error rate). In Part IV, an evidential model of scientific inquiry is presented that views knowledge as defeasible. On this model, a proposition is classified as knowledge in a scientific inquiry if it is accepted as supported strongly enough by the evidence to meet an appropriate standard of proof even though it may have to retracted later, once new data comes in that proves it to be no longer acceptable as knowledge. In the model, a proposition *p* does not have to be true to be included in knowledge, but falsifiability holds. If it is shown to be false, it has to be rejected as part of scientific knowledge. In Part V, it was contended that the external epistemology of scientific evidence is determined by how the internal elements of scientific evidence are used in an external procure for fact-finding in a legal setting, including the credibility of expert witnesses, the beliefs fact-finders place on scientific evidence, and justification for these beliefs. The ESE plays a fundamental role in decision making to admit or exclude scientific evidence by fact-finders, therefore, in Part VI, this article critically reviewed the standards of admissibility of scientific evidence from an epistemological point of view, and argued that the reliability of scientific evidence is not free of difficulties as a rule, but an epistemological standard for its admissibility is available. The admissibility of scientific evidence should depend (1) on its internal reliability, based on scientific validity; (2) on the credibility of expert witness testimony; and (3) the standard of admissibility should be decided by the justification for beliefs about scientific evidence. Part VII drew the conclusions that (1) truth-finding based on scientific evidence is a procedure for justifying fact-finders' reasonable beliefs and (2) justification for beliefs about scientific evidence maps a belief onto a dichotomous legal choice on admissibility.

In this paper we have taken an approach that is different in four key respects from the viewpoint of traditional epistemology in analytical philosophy. First, we reject the principle that knowledge has to imply truth by deductive logic. Our view is based on the premise that scientific knowledge is defeasible, a premise we have argued for. Second, we have adopted an evidence-based epistemology according to which scientific knowledge is based on critical analysis of evidence both for and against a hypothesis. Third, instead of defining scientific knowledge in terms of justified true belief, we define it as something that is achieved through a process of marshaling evidence in a scientific inquiry, and represents a species of firmly fixed belief set in place by a convergence of scientific theories and research results. Fourth, we don't see scientific knowledge exclusively in light of this internal procedure of an inquiry only participated in by the scientists who are specialists in a particular field or area of science. We also see scientific knowledge as something that needs to be identified, evaluated and used in other settings, notably in law and other settings of public policy decision-making, for example in legislative assemblies.

It is worth strongly emphasizing that our view of scientific knowledge should not be seen as taking it to be an exclusively internal concept. Evaluating scientific evidence is a task that needs to be undertaken both internally in science, and externally in legal and other settings. To support this view we have argued that the dialogue interface of argument from expert opinion along with its set of critical questions provides an argumentation framework that shows how the ESE theory is feasible. It enables internal scientific knowledge to be translated over into a wider arena in which individual non-expert citizens and groups can make use of it. They take a hypothesis as scientific because they can understand it well enough to base rational arguments on it, subject to the limitation of not being experts themselves.

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