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The Concept of Baseline Risk in Tort Litigation

BY VERN R. WALKER*

INTRODUCTION

Inherent in most current theories of what constitutes an unintentional tort is an inchoate concept of "normal risk."¹ Generally, plaintiffs are not allowed to recover compensation for injuries resulting from the ordinary, daily risks faced by members of the general population. A defendant may become liable, however, by creating an "unreasonable risk" that brings about a plaintiff's injury.² Negligence is determined by applying the standard of conduct of a reasonable person under similar circumstances.³ By contrast, the normal risks created by reasonable activity are part of the danger inherent in living in society and are not a proper predicate for awarding tort damages.⁴

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¹ This Article addresses only those torts considered at law to be unintentional or accidental.

² *E.g.*, RESTATEMENT (SECOND) OF TORTS § 281 & cmt. e (1965) (noting that actor liable if, among other things, actor's conduct is negligent—that is, the conduct "tends to subject the interests of [the plaintiff] to an unreasonable risk of harm"); *id.* § 282, (defining negligence as conduct that falls below standard established for protection of others "against unreasonable risk of harm").

³ *E.g.*, *id.* § 283.

⁴ On occasion, courts and commentators have expressly articulated the principle that normal risks are not unreasonable. *See, e.g.*, *O'Gilvie v. International Playtex, Inc.*, 821 F.2d 1438, 1443-44 (10th Cir. 1987) (holding that decedent, who died of toxic shock syndrome, did not act unreasonably in continuing to use tampons in disregard of package warning after being reassured by her doctor that she did not have toxic shock syndrome), *cert. denied*, 486 U.S. 1032 (1988); *Allman v. Holleman*, 667 P.2d 296, 300 (Kan. 1983) (holding, as a matter of law, that decedent was not contributorily negligent in taking birth control pills pursuant to doctor's prescriptions, because "nearly all human acts carry with them some degree of risk," and when that risk is slight enough so as to be commonly disregarded, the standard of care is not violated); *W. PAGE KEETON ET AL., PROSSER AND*

When liability is determined by reference to the negligence principle, for example, tort law does not require defendants to be "insurers" against all risks, and provides a remedy only for injuries traceable to unreasonable risks beyond the risks normally encountered. When tort law provides compensation without reference to negligence, a notion of non-compensable normal risk is also at work. Injuries traceable to risks from "ultrahazardous" or "abnormally dangerous" activities may be compensable in strict liability,⁵ but such risks and activities are identified only in contrast to the "normally risky" activities in which people engage.⁶ In the area of strict products liability, injuries due to normal risks faced by users of non-defective products are not compensable by the supplier.⁷ Thus, even in areas where tort law invokes strict liability,

KEETON ON THE LAW OF TORTS § 31, at 170 (5th ed. 1984) ("Nearly all human acts, of course, carry some recognizable but remote possibility of harm to another. No person . . . drives a car without the risk of a broken steering gear or a heart attack. But these are not unreasonable risks.").

⁵ See, e.g., *Doundoulakis v. Town of Hempstead*, 368 N.E.2d 24, 27, 30 (N.Y. 1977) ("With respect to strict liability it is not every dangerous activity which will establish liability. It is only when, under the circumstances, an activity is abnormally dangerous that the actors become legally responsible."); *Peneschi v. National Steel Corp.*, 295 S.E.2d 1, 4-11 (W.Va. 1982) (holding that when a person chooses to use an abnormally dangerous instrumentality he is strictly liable without a showing of negligence for any injury proximately caused by that instrumentality); RESTATEMENT (SECOND) OF TORTS § 519 (1977).

⁶ In addition, if the injury suffered is not the type of injury traceable to the abnormal risk created by the activity, then strict liability generally does not apply. RESTATEMENT (SECOND) OF TORTS § 519(2) (1977) (limiting strict liability "to the kind of harm, the possibility of which makes the activity abnormally dangerous"); e.g., *Peneschi*, 295 S.E.2d at 6 ("[T]he rule of strict liability applies only to that harm which is within the scope of the abnormal risk upon which liability is based.").

Liability for injuries from normal risks (e.g., the risk of injury from falling objects), even though encountered in abnormally dangerous activities (e.g., operating an explosives manufacturing facility), is governed by the negligence principle, not strict liability. See, e.g., *Herman v. Welland Chem., Ltd.*, 580 F. Supp. 823, 826 (M.D. Pa. 1984) (dismissing absolute liability counts of volunteer firemen struck by car while directing traffic following chemical spill on highway, although court assumed that doctrine of absolute liability could be applied to shipment of chemicals); *Harper v. Regency Dev. Co.*, 399 So. 2d 248, 253 (Ala. 1981) (stating that if someone trips over dynamite and breaks a leg, but no explosion takes place, strict liability will not apply); RESTATEMENT (SECOND) OF TORTS § 519 cmt. e (1977) (noting that pedestrian run over by truck transporting dynamite through city streets not able to recover on strict liability).

⁷ See RESTATEMENT (SECOND) OF TORTS § 402A & cmt. i (1965) (predicating strict liability on product being "in a defective condition unreasonably dangerous," meaning that "[t]he article sold must be dangerous to an extent beyond that which would be contemplated by the ordinary consumer who purchases it, with the ordinary knowledge common to the community as to its characteristics"); see also *Borel v. Fibreboard Paper Prods. Corp.*, 493 F.2d 1076, 1087 (5th Cir. 1973) ("[L]iability may not be imposed merely because a product involves some risk of harm or is not entirely safe for all uses. Products liability does not

defendants are still not regarded as insurers against the normal risks of life.

The policy of excluding from tort compensation those injuries due to normal risks also underlies the causation requirement in a tort cause of action, whether sounding in negligence or strict liability. The plaintiff must establish that the defendant actually caused the injury—that is, that the injury did not result from risks that the plaintiff otherwise would have encountered.⁸ Injuries not caused by the defendant's activities or omissions are generally not chargeable to the defendant.⁹ The causation requirement acts as an additional means of ensuring that a defendant is not held liable for injuries due to the normal risks that would have been present regardless of the defendant's activities.

Perhaps because the concept of normal risk is so intuitive and fundamental to tort law, the cases have not evolved a standard or well-defined terminology. Normal risk has been referred to as the "everyday" or "usual" risk associated with an activity or situation.¹⁰ Such risks have been described as "pervasive," "common,"

mean that a seller is an insurer for all harm resulting from the use of his product." Product is "defective" only if it is unreasonably dangerous, not simply dangerous.), *cert. denied*, 419 U.S. 869 (1974).

⁸ This is clearest when the concept of causation employed is "but for" causation, in which the defendant's negligent act (for example) must be a necessary condition for the plaintiff's injury. *E.g.*, KEETON ET AL., *supra* note 4, § 41, at 266. Essentially, had it not been for the defendant's conduct, plaintiff would not have been injured. *See infra* text accompanying notes 146-150.

The notion of a defendant not compensating for what would have normally happened anyway is less clearly present in a "substantial factor" concept of causation, *see* KEETON ET AL., *supra* note 4, § 41, at 266-68, which is sometimes applied when either of two causes (only one of which is the defendant's responsibility) would have been sufficient to bring about the injury. The concept of baseline risk should prove useful in clarifying what is meant by the substantiality of a factor. *See infra* text accompanying note 151.

⁹ *E.g.*, *Lekas & Drivas, Inc. v. Goulandris*, 306 F.2d 426, 430 (2d Cir. 1962) ("[I]f the accident would have happened without defendant's negligent act, then such is not the cause of it." (quoting 2 FOWLER V. HARPER & FLEMING JAMES, JR., *THE LAW OF TORTS* § 20.2, at 1114 n.18 (1956))); *Livingston v. Gribetz*, 549 F. Supp. 238, 243 (S.D.N.Y. 1982) (holding that because an act or omission is not regarded as a cause of an event if the particular event would have occurred without it, no causation established where plaintiff nurse could have contracted herpes simplex through various means under the circumstances, regardless of defendant pediatrician's actions); RESTATEMENT (SECOND) OF TORTS § 432(1) (1965) (actor's negligent conduct "not a substantial factor in bringing about harm to another if the harm would have been sustained even if the actor had not been negligent").

¹⁰ *See, e.g.*, *Jackson v. Kansas City*, 680 P.2d 877, 892 (Kan. 1984) (holding collision between fire trucks on emergency runs not, as a matter of law, a "usual risk" of a fire fighter's employment); *McLaughlin v. Rova Farms, Inc.*, 266 A.2d 284, 296 (N.J. 1970) (distinguishing the "ordinary and usual risks" of diving and swimming inherent in the

or "general."¹¹ They might also be referred to as the "natural" risks of life, or the risks associated with the "accidental," "random," or "chance" events inherent in life.

Such variation in terminology, however, also reflects an imprecision in judicial thinking about normal risk—an imprecision that has been tolerable because the rationales for deciding cases have been constructed with such concepts as "unreasonable risk," "abnormally dangerous activity," "defective condition unreasonably dangerous," and "cause." But as serviceable as these front line concepts have been, their usefulness has been severely tested by the complexity of modern cases, especially those involving scientific theories about risk determination and scientific information about normal risk. The advent, for example, of tort claims involving latent injuries¹² or "lost chances" for benefit,¹³ and the increased

sport, and any "extraordinary hazards" created by the defendant); Frank B. Cross, *Beyond Benzene: Establishing Principles for a Significance Threshold on Regulatable Risks of Cancer*, 35 EMORY L.J. 1 (1986) (discussing "average" health risks).

¹¹ See, e.g., *Ek v. Herrington*, 738 F. Supp. 357, 361 (D. Idaho 1990) (noting that hauling of lumber creates a number of "common risks," as distinct from "peculiar risks"), *aff'd*, 939 F.2d 839 (9th Cir. 1991); *Kerr-McGee Corp. v. Hutto*, 401 So. 2d 1277, 1281 (Miss. 1981) (describing the "general risk" of employment).

¹² See, e.g., *Sterling v. Velsicol Chem. Corp.*, 855 F.2d 1188, 1192, 1204-05 (6th Cir. 1988) (holding that district court properly held defendant liable for injuries caused by leaching of waste chemicals from landfill into drinking water, but requiring that damages for mere increased risk of future disease be excluded unless a reasonable medical certainty existed that the relevant harm would actually result); *Herber v. Johns-Manville Corp.*, 785 F.2d 79, 81-83 (3d Cir. 1986) (holding that district court properly excluded evidence of present increased risk of possible future cancer when plaintiff that was diagnosed as having pleural thickening of the lungs did not present sufficient evidence that he would more likely than not develop cancer in the future); *Lohrmann v. Pittsburgh Corning Corp.*, 782 F.2d 1156 (4th Cir. 1986) (disallowing plaintiff that allegedly had contracted asbestosis from introducing evidence of cancer risk because he could not establish a reasonable probability that cancer would develop); *In re "Agent Orange" Prod. Liab. Litig.*, 597 F. Supp. 740, 834 (E.D.N.Y. 1984) (tentatively approving fairness of settlement, partly because, if the incremental incidence of soft-tissue sarcoma among those exposed to Agent Orange is equal to or less than the incidence in the general population not exposed to Agent Orange, and if there is no meaningful causal proof specific to particular plaintiffs, "virtually no plaintiff would be able to show by a preponderance of the evidence that his or her cancer is attributable to the Agent Orange rather than being part of the 'background' level of cancer in the population as a whole"), *aff'd*, 818 F.2d 145 (2d Cir. 1987), *cert. denied*, 484 U.S. 1004 (1988); *Brafford v. Susquehanna Corp.*, 586 F. Supp. 14 (D. Colo. 1984) (addressing plaintiffs' claim that waste material from processing of uranium ore placed in and around foundation of their home exposed them to levels of radiation greatly in excess of those permitted by governmental regulatory standards and dramatically increased their risk of cancer).

¹³ See, e.g., *Falcon v. Memorial Hosp.*, 462 N.W.2d 44, 52 (Mich. 1990) (holding that compensable injury from medical malpractice includes loss of opportunity of avoiding physical harm, even though the opportunity lost was less than even); *Hamil v. Bashline*,

pressures to regard risk itself as a compensable injury,¹⁴ have created the need to rethink and refine such concepts as "unreasonable risk" and "proximate cause."¹⁵ Such cases also create pressure to reexamine the relationship between scientific evidence of risk and such legally required factual elements as negligence and causation.

The objective of this Article is not to resolve all the substantive issues raised by such difficult cases, let alone to propose redesigns of such legal concepts as negligence and causation. The objective is necessarily more limited: it is to provide an important part of the conceptual foundation for undertaking those tasks. This Article examines what is meant, or should be meant, by "normal risk," and how to determine what the "normal risks" are in a given situation.

This Article proposes a new legal concept: "baseline risk."¹⁶ The objective is to design a concept of baseline risk that should prove useful in tort litigation by clarifying what is meant by "normal risk" and providing a well-defined concept upon which a reevaluation of traditional tort concepts might rest. A more precise notion of "normal risk" may assist in improving the designs of such traditional tort concepts as "unreasonable risk," "abnormally dangerous activity," "product defect," and "causation"—concepts that are stubbornly vague in increasingly unproductive ways.

392 A.2d 1280, 1286-88 (Pa. 1978) (holding that when expert witness testified that if hospital emergency room had employed proper treatment, decedent would have had substantial chance of surviving heart attack, jury should decide whether the increased risk due to defendant's actions was a substantial factor in producing the harm); *Herskovits v. Group Health Coop.*, 664 P.2d 474, 486-87 (Wash. 1983) (allowing cause of action to be tried when plaintiff produced sufficient evidence that misdiagnosis of lung cancer proximately caused a 14 percentage-point reduction in plaintiff's chances of survival even though plaintiff at all relevant times would have had less than 50% chance of survival absent misdiagnosis). For other cases allowing causation to be found on proof that the defendant's conduct increased the risk of death by decreasing the chances of survival, see *McBride v. United States*, 462 F.2d 72 (9th Cir. 1972); *Hicks v. United States*, 368 F.2d 626 (4th Cir. 1966); *Kallenberg v. Beth Israel Hosp.*, 357 N.Y.S.2d 508 (N.Y. App. Div. 1974). See also Joseph H. King, Jr., *Causation, Valuation, and Chance in Personal Injury Torts Involving Pre-existing Conditions and Future Consequences*, 90 YALE L.J. 1353 (1981).

¹⁴ See cases cited *supra* note 12.

¹⁵ See, e.g., Jack B. Weinstein & Eileen B. Hershenov, *The Effect of Equity on Mass Tort Law*, 1991 U. ILL. L. REV. 269, 270-73 (explaining that toxic tort cases, due to their complex medical and scientific issues of proof, present the legal system with the most difficult dilemmas, which traditional tort doctrines, with their relatively simple models of causation and liability, are ill-equipped to address).

¹⁶ The term "baseline risk" is used exclusively to refer to the specific concept herein defined, thus enabling a contrast between the new concept and the inchoate notions of "normal risk" that pervade traditional tort law.

Moreover, given the increasing importance of scientific evidence in tort litigation, a concept of baseline risk will be particularly useful to the extent that it clarifies what scientific evidence is relevant to determining normal risk in a given situation. One practical benefit that might be derived is a clearer basis upon which to decide summary judgment motions, evidentiary motions *in limine*, and motions for directed verdict. It is hoped, therefore, that the concept of baseline risk will enable more efficient utilization of scientific evidence in tort litigation.

Finally, the interplay between tort and statutory bases for legal remedy, and the increased importance of the concept of risk in both judicial and regulatory decision making, make a single, reasonably precise concept of baseline risk desirable.¹⁷ As defined here, the concept of baseline risk should provide part of the foundation for a conceptual bridge between tort theories of compensation for past injuries and statutory and regulatory programs that prospectively manage health, safety, and environmental risk. Such a foundation is needed before a unified theory of accident law can be developed.

This Article is organized into three major parts. Part I discusses the concept of risk in general and sets forth a basic formulation of the concept of baseline risk.¹⁸ Part II discusses several major kinds of uncertainty or error usually associated with baseline risk. That Part also explores a basic paradox (the "baseline risk paradox") associated with determining specific causation in particular cases and suggests that this paradox is the conceptual problem underlying both "lost chance" cases and the "indeterminate plaintiff" problem.¹⁹ Part III discusses appropriate uses of the concept of baseline risk in tort litigation, focusing particularly on its rele-

¹⁷ Although statutes and regulations intended to protect health, safety, and the environment are not the topic of this Article, it is worth noting that many of such laws also rely on an implicit concept of normal or "background" risk. See, e.g., Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), 7 U.S.C. §§ 136-136y, 136(bb), 136a(c)(5) (1988) (regulating pesticides so as to avoid "unreasonable adverse effects," "unreasonable risk"); Consumer Product Safety Act (CPSA), 15 U.S.C. §§ 2051-2084, 2057 (1988) (regulating "banned hazardous products" by reference to "unreasonable risk of injury"); Toxic Substances Control Act (TSCA), 15 U.S.C. §§ 2601-2671, 2603(a), 2604(f), 2605(a) (1988) (regulating chemicals with respect to "unreasonable risk of injury"); Resource Conservation and Recovery Act (RCRA), 42 U.S.C. §§ 6901-6992k, 6903(5) (1988) (defining "hazardous waste" in terms of, in part, "an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness").

¹⁸ See *infra* part I.

¹⁹ See *infra* part II.

vance to certain factual elements of traditional causes of action, as well as the proper allocation of the burdens of production and persuasion on baseline risk.²⁰

I. THE CONCEPT OF BASELINE RISK: BASIC FORMULATION

This Part introduces the basic elements of "risk," applies these elements to tort litigation, and arrives at a basic formulation of baseline risk.

A. *The Elements of Risk*

"Risk" is generally defined as the probability or likelihood of suffering harm from a hazard.²¹ A "hazard," in turn, is any action or substance that can cause harm.²² It is common, however, also to refer to the harm that can be caused as a hazard.²³ Thus, the word "hazard" is used to refer either to the cause of the harm (the external agent) or to the resulting harm (the type of injury). The "hazard event" is the accident itself: the occurrence or event consisting of the harm-causing agent's actually causing the harm. An example of a hazard event is the ingestion of a toxic chemical; either the chemical itself or the resulting toxic reaction could be referred to as the hazard.

Risk theory—and probability theory itself—originated in part as a study of gambling or games of chance,²⁴ which still provide clear examples of what is meant by risk. Risk can be measured by the expected loss associated with the possibility that a hazard event might occur (i.e., the probability of the hazard event occurring

²⁰ See *infra* part III.

²¹ See, e.g., JOHN J. COHRSEN & VINCENT T. COVELLO, *RISK ANALYSIS: A GUIDE TO PRINCIPLES AND METHODS FOR ANALYZING HEALTH AND ENVIRONMENTAL RISKS* 6-7 (1989) (defining "risk" as "the possibility of suffering harm from a hazard"); NATIONAL RESEARCH COUNCIL, *RISK ASSESSMENT IN THE FEDERAL GOVERNMENT: MANAGING THE PROCESS* 18 (1983) (defining "risk assessment" as "the characterization of the potential adverse health effects of human exposures to environmental hazards"); WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY 1961 (1986) (defining risk as "possibility of loss, injury, disadvantage, or destruction," "the chance of loss or the perils to the subject matter of insurance covered by a contract," and "the degree of probability of such a loss").

²² COHRSEN & COVELLO, *supra* note 21, at 1.

²³ See, e.g., WEBSTER'S THIRD NEW INTERNATIONAL DICTIONARY, *supra* note 21, at 1041 (defining hazard as "a thing or condition that might operate against success or safety," "a possible source of peril, danger, duress, or difficulty").

²⁴ R. DUNCAN LUCE & HOWARD RAIFFA, *GAMES AND DECISIONS* 19 (1957); STEPHEN M. STIGLER, *THE HISTORY OF STATISTICS* 62 (1986).

multiplied by the amount of the loss if it occurs). Selecting "heads" as the winning side of the coin converts tossing "tails" into a hazard event. The expected loss in the toss of a fair coin on which a bet has been placed is the probability that the toss will result in showing the side of the coin ("heads" or "tails") not chosen by the gambler, times the amount wagered.

Colloquially, many say that a significant risk associated with driving seventy miles per hour on a wet, curved road is losing control of the vehicle (the hazard event), but that the risk is "less" if the road is dry and straight. Salmonella poisoning (the effect of ingesting salmonella) is "a risk" run from eating certain undercooked foods; the magnitude of the risk depends on many factors. In this sense, "a risk" is a hazard event that has some non-zero or non-negligible probability of occurring.²⁵ When certain *conduct* is described as "risky," that usually means that engaging in it creates or incurs a non-zero probability of some hazard event occurring. When a *situation* is described as "risky," the label ordinarily means that the circumstances are such that being (or acting) in that situation incurs some risk—that is, has associated with it a hazard event with a non-zero probability of occurrence.

Determination of risk can be approached qualitatively or quantitatively. Whether or not certain activities or situations have certain risks associated with them is a qualitative, "yes-or-no" matter.²⁶ Driving an automobile has certain risks associated with it that staying home in bed (normally) does not; eating uncooked shellfish

²⁵ The distinction between a "non-zero" probability and a "non-negligible" probability can be important. See, e.g., *Public Citizen v. Young*, 831 F.2d 1108, 1109, 1122 (D.C. Cir. 1987) (holding that the FDA cannot allow use of a color additive as "safe" if the color additive fails to meet the applicable "Delaney Clause," even if the additive presents only a *de minimis* or "trivial" risk to humans), *cert. denied*, 485 U.S. 1006 (1988). For purposes of this Article, however, and in much of everyday usage, the distinction is not important, in the sense that an extremely small, negligible risk is often regarded as not a "real risk" at all.

Fortunately, a determination of the quantitative threshold of probability for identifying a "real risk," as opposed to a "non-risk," is not necessary in this Article. This is part of the problem of defining such qualifiers as "safe" and "de minimis risk," which is a problem currently haunting such regulatory agencies as the FDA. The analysis in this Article does not depend on being able to identify the exact line in close cases. Moreover, there is no reason to think that a single line should be drawn for all purposes: depending on the potential costs and benefits involved, and the degree of uncertainty about risks, a rare event that is dismissed as negligible in some circumstances may well be considered a serious risk in others. Such determinations of "real risk" are ideally suited for jury determination.

²⁶ See COHRSEN & COVELLO, *supra* note 21, at 6 (defining "hazard identification"); NATIONAL RESEARCH COUNCIL, *supra* note 21, at 19 (same).

has risks that bungee jumping does not. A particular chemical can either cause a given health effect (e.g., cancer) or it cannot. Risk identification, in this qualitative sense, is a matter of identifying the relevant hazard (harmful agent or resulting harm) and determining whether there is any non-negligible possibility of its occurrence.

More difficulty enters if the inquiry moves beyond mere qualitative identification of risk into ranking risks or measuring them quantitatively. This is usually done for the purpose of comparing risks or balancing risks against potential benefits. The least controversial part of risk measurement is determining the probability of occurrence. This Article assumes a classical or relative frequency interpretation of probability statements and assumes that the standard mathematical theory of probability (so interpreted) is an adequate means of measuring the likelihood of a hazard event occurring.²⁷ For the same harm or loss, therefore, a 40% chance of its occurring creates twice the risk that a 20% chance would create. If all else is equal, risks can be measured and compared on the basis of their probability of occurrence.

Once measurements and comparisons are attempted beyond the level of mere probability of occurrence, however, more serious conceptual problems arise. Quantifying expected loss,²⁸ ranking different types of harm or loss, or comparing the harms caused to different people, for example, are problems for which there is no consensus on measurement. To weigh a 50% loss of mobility in one person's right arm against the destruction of another's personal property involves principles that are problematic, and factors that vary from person to person, from circumstance to circumstance.²⁹

²⁷ The concept of baseline risk could be defined using a "subjectivist" or "personalist" interpretation of probability statements, and Bayesian inferential statistics could be employed throughout the Article. See generally Vern R. Walker, *The Siren Songs of Science: Toward a Taxonomy of Scientific Uncertainty for Decisionmakers*, 23 CONN. L. REV. 567, 618-24 (1991). Doing so should not change any of the basic analysis or conclusions. Therefore, in order to explicate the concept of baseline risk in the most straightforward way, this Article uses the somewhat simpler, classical, "frequentist" interpretation, with which most readers are familiar. See *infra* text accompanying notes 35-39.

²⁸ This Article need not explore the extremely difficult topic of proper valuation of injury, including economic and noneconomic losses (e.g., lost wages and suffering, respectively). It is sufficient for present purposes to note that the jury system is a procedure for arriving at such valuations.

²⁹ The right side of Judge Learned Hand's celebrated inequality requires a calculation of the value of the expected loss—in that case, an estimate of the magnitude of the risk associated with not having a bargee on board the barge "Anna C." See United States v.

Although such problems might not be avoidable were this Article to analyze such concepts as "*unreasonable risk*," the concept of baseline risk is definable without entering that particular swamp.

In analyzing baseline risk for purposes of tort litigation, two issues must be clarified. The first issue is how to identify the hazard event that is relevant to the litigation. The second is how to identify the probability of occurrence of such a hazard event. After a brief discussion of these two issues, it will be possible to formulate, at least in a basic way, the concept of baseline risk.

B. The Hazard Event in Tort Litigation

Tort litigation departs in a fundamental way from the model of decision making in which a decider must take into account a proliferating set of possible outcomes to each of a range of possible decisions.³⁰ For example, in the game of draw poker a player may decide to draw additional cards, not draw cards, or "fold," and she may bet or "check." Various combinations of these possible actions can have one of many possible outcomes, depending on what other players do and the value of the hands that they hold. Another example of this normal, prospective model is a regulatory agency whose statutory mandate is to identify hazards associated with its actions.³¹ Tort litigation, however, is generally concerned neither with identifying possible hazard events in general, nor with determining their prospective probabilities of occurrence. In a simplified case involving a single injury to a plaintiff, the relevant hazard is the specific kind of injury already suffered by the plaintiff, and the relevant hazard event is the plaintiff's accident. Other

Carroll Towing Co., 159 F.2d 169, 173 (2d Cir. 1947) (suggesting that negligence occurs when the "burden of adequate precautions," B, is less than or equal to the "gravity of the resulting injury," L, multiplied by the probability of the injury's occurring, P: $B \leq PL$). For the mere existence of some risk, however, all that is required is a non-zero or non-negligible likelihood of a loss or injury.

³⁰ See, e.g., HERMAN CHERNOFF & LINCOLN E. MOSES, *ELEMENTARY DECISION THEORY* 2-9 (1959); LUCE & RAIFFA, *supra* note 24, at 276-77.

³¹ The EPA, for example, in the registration process for a pesticide under the Federal Insecticide, Fungicide, and Rodenticide Act, 7 U.S.C. §§ 136-136y (1988), takes into account possible detrimental effects to human health and the environment. See *id.* §§ 136(j), 136a(c)(5)(C)-(D); see also 40 C.F.R. Part 158 (1991) (requiring an applicant for registration to submit data addressing such questions as the human toxicology and environmental fate of the product). As part of a regulatory risk assessment, the Agency, before registering a pesticide, attempts to determine whether exposure to an agent in the pesticide can cause an increase in the incidence of an adverse health condition. See NATIONAL RESEARCH COUNCIL, *supra* note 21, at 19.

kinds of hazards and hazard events are usually regarded as irrelevant to the liability of the defendant.³²

Tort litigation, unlike regulatory decision making, has the advantage of being able to focus the factual inquiry retrospectively, by determining the chain of events and risks relevant to the actual injury suffered by the plaintiff. The inquiry can focus upon a particular injury (e.g., broken leg, lung cancer), and often upon a particular hazard event (e.g., automobile collision, breathing contaminated air).³³ Tort analysis works "backward" in time, proceeding from the injury to the accident, and from the accident to the defendant's actions and the associated risk that those actions could bring about that injury. The trier of fact in tort litigation normally considers only those circumstances, actions, factors, and risks that are relevant to the particular injury actually suffered. Such an analysis can proceed relatively efficiently, especially when compared to open-ended, prospective fact-finding.

The nature of the plaintiff's actual injury and of the accident, therefore, are the major factors in determining the relevance to the litigation of particular risks. Tort law seeks to compensate the plaintiff for actual injuries due to unreasonable risks created by the defendant, not to compensate for injuries that would have been suffered regardless of the defendant's actions.³⁴ To the extent, therefore, that liability rests on responsibility for the creation of risks, the risks that are relevant to the litigation are determined solely by the kind of hazard and hazard event associated with the plaintiff's injury. The only actions of the defendant that are usually directly relevant to the case are those actions that could have contributed to the risk of the particular kind of injury suffered by the plaintiff.

³² Other hazard events may be relevant to the measurement of damages. In determining the appropriate amount of damages, the jury and court may properly take into account the actual life expectancy of the plaintiff prior to the accident, which is a unitary measure of the plaintiff's risk of death from all kinds of hazards. See DAN B. DOBBS, *HANDBOOK ON THE LAW OF REMEDIES* 571-73 (1973). The discussion here, however, sets to one side considerations of damages, and addresses rather the assessment of liability for the injury suffered by the plaintiff.

³³ It is sometimes possible to identify the relevant harm, but not the specific hazard event. If a person is ill in recurring ways, there might be good reason to think that the illness is being caused by exposure to some environmental agent, but very little indication as to what that environmental agent is or when the person was exposed to it.

³⁴ See, e.g., *RESTATEMENT (SECOND) OF TORTS* § 901 & cmt. a (1979) (limiting damages to those that tend to carry out the stated purposes of tort law).

C. *Likelihood of Occurrence*

The mathematical theory of probability is generally used to define what is meant by the "likelihood of occurrence" of an event.³⁵ This Article presupposes the workability of a frequentist interpretation of probability,³⁶ in which the probability of an event is the expected, long-run frequency of occurrence of that event relative to the same or similar circumstances.³⁷ The likelihood or probability of a particular hazard event occurring, therefore, is the relative frequency with which one would expect that hazard event to occur in the relevant circumstances. In the circumstances of throwing a fair die, the probability of throwing a "2" is 1/6: that is, in the long run, we expect that approximately 1/6 of the total number of throws would result in a "2." Similarly, the probability of a rare complication to a particular kind of surgery might be 1/1,000—by which we mean that the complication is expected to occur about once for each 1,000 operations performed.

In the tort context, the probability of the plaintiff's injury can be defined as the ratio of two sets of events. The first set of events is defined by the hazard or hazard event itself, to be referred to as the "hazard set." The hazard set is the set of occurrences of the type of injury (hazard) or accident (hazard event) suffered by the plaintiff (e.g., death by complications of surgery, salmonella poisoning).³⁸ The second set of events, to be referred to as the "reference set," is the set of *all* possible outcomes in the situation or circumstances in which the plaintiff was injured.³⁹ The reference set includes the hazard set as a subset, but also includes other hazards that did not eventuate under the particular circumstances, as well as any outcomes that are harmless and do not include injury to the plaintiff.

³⁵ For discussions of alternative interpretations for the elements of a probability function (such as propositions or sentences, instead of events or sets of events), see, for example, HENRY E. KYBURG, JR., *PROBABILITY AND INDUCTIVE LOGIC* 12-13, 54-76 (1970).

³⁶ For surveys of alternative interpretations for probability statements themselves (such as logical or subjective interpretations, instead of a frequency interpretation), see COLIN HOWSON & PETER URBACH, *SCIENTIFIC REASONING: THE BAYESIAN APPROACH* 21-23 (1989); KYBURG, *supra* note 35, at 29-76; Max Black, *Probability*, in 6 *THE ENCYCLOPEDIA OF PHILOSOPHY* 464, 473-78 (Paul Edwards ed., 1967).

³⁷ See, e.g., CHERNOFF & MOSES, *supra* note 30, at 89; KYBURG, *supra* note 35, at 40-53; Black, *supra* note 36, at 475-76.

³⁸ In the example of throwing the die, the hazard set consists of throwing a "2."

³⁹ In the case of the die, the set of all possible outcomes has 6 members: throwing a result from "1" to "6."

The probability of the plaintiff's injury under the circumstances in which the accident occurred (that is, the probability of the occurrence of the harm or hazard event in the situation) is the expected, long-run relative frequency with which that type of hazard event and injury would occur in the same or similar circumstances. Thus, in determining the likelihood of occurrence of the plaintiff's injury, the number of total outcomes in a long series of "trials" in similar circumstances is the denominator of the probability ratio, while the frequency of occurrence of the harm or hazard in that series is the numerator. The resulting probability is the likelihood of the plaintiff's injury or accident relative to the situation.

In this ratio, the denominator (the number of total outcomes) is simply the number of "trials" (for example, throws of the die). However, counting the number of trials presupposes that we have sufficiently well-defined criteria for what will count as a trial. In torts, the criteria for what will count as a trial are sometimes referred to implicitly in the phrase "same or similar circumstances."⁴⁰ Those same or similar circumstances constitute the "situation" in which the accident occurred—whether highway conditions, an occupational situation, or a hospital surgical setting. In determining the baseline risk for the plaintiff's injury, the trier of fact should restrict consideration to situations similar to those in which the plaintiff found herself just prior to the accident, and should estimate the likelihood of the injury occurring in such circumstances. The relevant circumstances surrounding the accident, including those acts of the defendant or circumstances created by the defendant that allegedly imposed an incremental risk, constitute the "reference situation," or simply "the situation."⁴¹

⁴⁰ In determining negligence, for example, the jury is usually instructed to take into account all the relevant circumstances. See, e.g., CALIFORNIA JURY INSTRUCTIONS, CIVIL, BOOK OF APPROVED JURY INSTRUCTIONS [BAJI] § 3.10 (7th ed. 1986). Of course, this instruction is given when asking the jury to decide what a reasonably prudent person in the *defendant's* position would do in the same or similar circumstances, and the attention is on the *defendant's* situation. This Article, by contrast, focuses on the set of same or similar circumstances surrounding the *plaintiff* to determine the baseline risk for the plaintiff's injury. The practical difference between the two concepts is minimal in the many situations in which the defendant's conduct occurs in the same situation as the plaintiff's injury (such as in an automobile collision case). The distinction is more significant when the defendant's relevant actions are spatially or temporally removed from the occurrence of the plaintiff's injury.

⁴¹ In contrast with the hazard and reference sets, which refer to types of outcomes (e.g., possible values on the die), the reference situation is comparable to the throwing of

Estimating a frequency of occurrence for the hazard event relative to the reference situation presupposes that hazard events can be reliably distinguished from non-hazard events, and that reference situations can be distinguished from non-reference situations. Statements about risk and relative frequency of occurrence, therefore, presuppose the possibility of a "count": a process by which outcomes and situations are sorted into categories.⁴² Unless there is consistency and consensus on such sorting, the count of the hazard occurrences as a proportion of the possible outcomes in the situation will change depending on who does the counting, or how an occurrence happens to be classified. Thus, in order to arrive at agreement on the likelihood for the occurrence of a hazard event, there must be agreement on how to classify "similar hazard events" and "similar circumstances."⁴³

To the extent that valid and reliable classification of hazard events and reference situations can be achieved, and the instances in each outcome set can be counted, an expected frequency of the

the die in a certain manner (e.g., shaking the die blindly in a cup and throwing it against the wall, or selecting a value to face upward and carefully releasing the die a mere inch above the table surface). The reference situation is the set of circumstances that includes all factors that can affect the outcome.

An alternative definition for the "reference situation" would be the same or similar circumstances, but *excluding* those acts of the defendant that are negligent. Such a definition would be practically unworkable, however, because one could not identify the reference situation without first deciding which acts of the defendant were negligent. Moreover, one would generally not know whether other (non-litigated) instances of similar circumstances involved any negligence, so it would be difficult to generate reliable statistics about the relative frequency of certain outcomes in the reference situation. It seems preferable, therefore, to define the reference situation as the set of all circumstances in which the plaintiff was situated, including any involvement the defendant may have had, but leaving open the question whether negligence was in fact involved.

"Baseline risk," as opposed to the "reference situation," will be defined to *exclude* consideration of the defendant's negligent acts. See *infra* part I.D. The reference situation, however, is defined as including all relevant risk factors, including any acts that may have been negligent.

⁴² Statistical scientists refer generally to "classification" or "measurement"—the process of classifying cases or "observations" into measurement categories, the results of which are recorded as data. See generally Walker, *supra* note 27, at 580-88. A principal objective behind measurement techniques is to achieve a procedure that will consistently produce the same classification of the same items or situations. Such consistency in classification is referred to as "reliability." E.g., EDWIN E. GHISELLI ET AL., MEASUREMENT THEORY FOR THE BEHAVIORAL SCIENCES 184, 191 (1981). Another objective is to produce "valid" classification methods—that is, measurement techniques that actually measure what we think they measure. E.g., GHISELLI ET AL., *supra*, at 266; HERMAN J. LOETHER & DONALD G. MCTAVISH, DESCRIPTIVE AND INFERENTIAL STATISTICS: AN INTRODUCTION 14, 32 (2d ed. 1980).

⁴³ For a discussion of the implications of measurement uncertainty, see *infra* part II.A.

accident relative to the reference situation can be determined. In a medical malpractice case, for example, the condition of the patient, together with the nature of the operation being performed, may define the reference situation. The possible outcomes for the patient might be sorted into two categories: death due to related causes within five years and survival for five years or more. If data exist on a representative set of such situations, an estimate of the expected, long-run relative frequency of death within five years for this kind of situation can be made.⁴⁴ Such a relative frequency is a ratio of deaths-within-five-years to all outcomes in the total number of situations studied and can be expressed as a relative frequency (e.g., 14 such deaths out of 124 cases), a proportion (14/124, or 0.1129), or a percentage (11.29%). This would be an estimate of the likelihood of occurrence of the harm (death within 5 years) given the reference situation.

D. *A Basic Formulation of Baseline Risk*

As stated at the outset, the concept of baseline risk is being designed to be useful in implementing the principle that injuries

⁴⁴ For a discussion of sampling uncertainty, see *infra* part II.C. One of the important functions of juries is to "intuit," in a non-systematic, non-quantitative manner, the "normal risks" associated with everyday situations, without the necessity for expert testimony or other specialized instruction. If a case involves an automobile collision on a straight, dry, well-marked paved road, in daylight, caused by the defendant's automobile crossing the centerline, the jury does not need expert guidance to infer that the normal risks associated with driving in such a situation are extremely small absent some additional factor, such as the defendant's negligence or a defect in the defendant's automobile. In a medical malpractice case, by contrast, the jury is not expected to possess a collective set of experiences from which it can infer an expected frequency of injury in similar circumstances. In such cases, the jury is not allowed to estimate, without expert assistance, the normal risks associated with the situation in which the injury occurred.

Another illustration of the important role of juries is provided by cases in which it is unclear which factors should comprise the baseline risk. For example, in *McMillan v. State Highway Commission*, 393 N.W.2d 332, 332-40 (Mich. 1986), the issue was whether placing on-energy-absorbing utility poles within three feet of the traveled portion of the highway created unreasonable risks for motorists. An alternative description of the issue is whether such poles should be regarded as part of the baseline risk of driving on the highway (and whether courts should decide this issue of baseline risk as a matter of law, or whether they should allow juries to decide on the facts of each case). The identification of the baseline risk has been traditionally a task for the jury. Juries have been helped in the task by the formal but general requirement (except in *res ipsa loquitur* cases) that the plaintiff must affirmatively argue what alternative, non-negligent conduct the defendant should have engaged in. See *infra* note 145 (noting that many courts require plaintiffs to produce evidence of an alternative, non-defective product design in cases where design defect is alleged). Thus, in choosing to argue whether the utility poles involved in the accident should have been placed six feet from the road, should have been designed differently, or should have been eliminated by under-grounding the utility lines, the plaintiff is in fact urging on jury a conception of acceptable baseline risks in the situation.

resulting from the normal risks of life are not compensable because they are part of the danger inherent in living in society. "Baseline risk" will be defined as the risk of occurrence of the plaintiff's injury or accident in the same or similar circumstances, *but* in the *absence* of any act of the defendant that in fact created an additional, unreasonable risk of the injury or accident. The baseline risk is, therefore, the relevant risk in the reference situation due to all factors other than the defendant's negligence.⁴⁵ It is the inherent, relevant risk even in the absence of the defendant's negligent acts or omissions. For example, in the malpractice situation, the baseline risk is the normal risk associated with undergoing the same kind of operation, under similar circumstances, when no malpractice occurs.⁴⁶ By definition, therefore, the total risk of the plaintiff's injury present in the reference situation is equal to the sum of the baseline risk and any incremental, unreasonable risk created by the defendant.

When the plaintiff contends that the defendant surgeon performed the operation "negligently," the plaintiff is asserting, *in part*, that the defendant performed some act, or failed to perform some act, that increased the risk to the plaintiff over the baseline risk associated with the operation. That incremental risk—the increase in risk due to the malpractice—is not part of the baseline risk: the baseline risk is the inherent risk in the reference situation absent the incremental risk created by the defendant's negligent act or omission. Traditional tort law has focused attention on the negligent act of the defendant, whereas the concept of baseline risk focuses attention on the risks created by all relevant causal factors *other than* the defendant's negligence.

Illustrations of the relevance of baseline risk to causes of action sounding in negligence, strict liability, nuisance, and products liability will be discussed in Part III. The objective at this point is simply to provide a basic formulation of the concept of baseline risk. Before exploring the usefulness of that concept in particular

⁴⁵ For purposes of exposition, this Article will refer to the defendant's "negligent act" or "negligence" as shorthand for "an act that created an additional, unreasonable risk of the plaintiff's injury or accident." As will become clear in Part III.A., however, the concept of baseline risk is broadly defined, so as to be relevant not only to negligent causes of action, but also to actions in strict liability, products liability, and nuisance, for example.

⁴⁶ In the collision situation, the baseline risk is the risk of physical injury due to collision in the absence of the defendant's negligence. In most collision cases, the baseline risk is negligible and therefore ignored in the litigation. See *supra* note 44.

tort areas, however, this basic understanding of the concept will be refined by examining the major kinds of uncertainty that are associated with trying to apply the concept.⁴⁷

II. TYPES OF UNCERTAINTY ASSOCIATED WITH BASELINE RISK

According to the basic formulation, baseline risk is an integrated function of all those risk factors inherent in the reference situation that are relevant to the plaintiff's injury, with the exception of the relevant risk created by the defendant's negligent acts or omissions.⁴⁸ Once the concept of baseline risk is defined, a number of important questions arise concerning the application of the concept and the uncertainty normally associated with determining baseline risk. Examining these difficulties will increase understanding of the concept itself. This Part of the Article attempts to refine the concept by discussing the kinds of uncertainty typically associated with estimating baseline risk.

A. *Conceptual and Measurement Uncertainty*

As previously indicated,⁴⁹ the determination of a probability of occurrence for a hazard involves counting its relative frequency of occurrence given the reference situation.⁵⁰ In order to identify frequency of occurrence, sufficiently valid and reliable criteria for identifying instances of the hazard set and instances of the reference situation must be available. If the analysis undercounts the hazard instances or overcounts the reference instances, it will underesti-

⁴⁷ Some readers may wish to turn directly to Part III to survey possible applications of the concept in torts contexts, using only the basic formulation presented thus far, before returning to Part II to refine their understanding of the concept.

⁴⁸ Scientists are rarely interested in bundling causally complex systems into a single package—for example, what in this paper and often in the law of torts is referred to as “the situation.” But in torts, the courts are not acting as investigative scientists, and it is often sufficient for legal purposes to divide the world of possible causes into only two parts: the defendant's negligent act and “other” risk factors.

For the sake of clarity, this Article considers only a two-party paradigm of a tort lawsuit, with a single plaintiff and a single defendant.

⁴⁹ See *supra* part I.C.

⁵⁰ This exposition will usually refer simply to the probability of the “occurrence of the hazard,” when what is meant more precisely is “the occurrence of an instance of the hazard set,” whether that set is defined by reference to the hazard event (the accident) or the hazard itself (meaning either the distinguishing kind of harm or the distinguishing characteristic of the harming agent). See *supra* part I.A.

mate the likelihood of occurrence of the hazard.⁵¹ On the other hand, overcounting hazard events or undercounting reference instances will result in overestimating the likelihood of occurrence. Central to the task of counting accurately, therefore, is the ability to classify events correctly and consistently as either hazard events or reference situations.

In the case of medical malpractice, the set of all similar situations would be the set of operations of that type being performed by comparably licensed or trained surgeons on patients with medical conditions similar to those of the patient.⁵² With respect to certain kinds of reference situations, there may be statistics available for average survival rates associated with particular operations based on the measurable condition of the patient.⁵³ Such survival statistics typically would be estimates based on the performed operations that have been documented and followed, which would exclude from consideration those similar operations that were performed but not documented, or for which no follow-up data were reported.

In most tort cases, however, frequency data about the reference situation and the hazard events relevant to the tort suit do not exist. The first difficulty is the conceptual uncertainty over how to identify the relevant variables.⁵⁴ Although a generic description of the kind of harm suffered by the plaintiff (e.g., death or poisoning)

⁵¹ Cf. ABRAHAM M. LILIENFELD & DAVID E. LILIENFELD, FOUNDATIONS OF EPIDEMIOLOGY 84-90 (2d ed. 1980) (discussing possible sources of artifactual error in mortality trends due to errors in the numerator or denominator of mortality rates).

⁵² The judicial rule that the standard of care in a medical malpractice case is the conduct of a reasonably competent practitioner, *see, e.g.*, *Robbins v. Footer*, 553 F.2d 123, 129 (D.C. Cir. 1977), effectively requires that the risks created by reasonably competent practitioners be within the baseline risk. The focus of this Article, however, is not on criteria for unreasonable risk, negligence, or medical malpractice, but on the concept of baseline risk.

⁵³ *See, e.g.*, *Herskovits v. Group Health Coop.*, 664 P.2d 474, 475 (Wash. 1983) (Over a span of 6 months, the decedent's possibility of 5-year survival with accurate diagnosis of lung cancer decreased from 39% to 25%).

⁵⁴ In developing a notion of relevant risk based on the hazard or hazard event, it is useful to employ the terminology of the statistical scientist. A "variable" is the property or characteristic of things or events that is the basis for sorting them into categories, or classifying them. *See generally* Walker, *supra* note 27, at 576-79. Balls might be classified by color (the variable) into many categories (e.g., black, red, white, etc.) or into only two (e.g., black and non-black). Similarly, types of hazard are classified by means of variables (e.g., variables addressing the identity or toxicity of a chemical agent or the health status of the plaintiff). In order to determine the baseline risk of an injury occurring, it is first necessary to define variables that allow us to identify instances of the reference situation and hazard.

may not present problems of definition, there may be no consensus on how to characterize the reference situation.⁵⁵ In most tort cases in which expert testimony is needed,⁵⁶ the question is whether the variables for which data exist can be used as sufficiently descriptive of the plaintiff's situation and hazard set.⁵⁷

One manifestation of the importance of estimating relative frequency in a lawsuit is that opposing attorneys often contend for alternative descriptions of the hazard event or of the relevant circumstances. For example, inclusion of more particularities or details in the description of the hazard event is likely to decrease its probability of occurrence, whereas a more general description is likely to increase its probability of occurrence.⁵⁸ Similarly, a more general description of the relevant circumstances would tend to increase the count of similar situations, which would tend to increase the number and types of nonhazard outcomes and lower the probability of the hazard event. A narrower description of the situation would tend to increase the probability of the hazard event. How trial attorneys define the hazard and reference situation, therefore, may influence the jury's intuitive estimation of risk.⁵⁹

⁵⁵ It should be kept in mind that the reference situation is defined by the set of all factors in the "same or similar circumstances" that may be relevant to bringing about the harm. Thus, the precise definition of the reference situation may be the subject of dispute within the litigation and may have to be resolved by the testimony of experts as to which environmental factors are important in establishing the baseline risk. At a minimum, the reference situation should be defined in such a way as to hold all significant relevant risk factors constant. See *supra* text accompanying notes 38-41; *infra* text accompanying notes 82, 109. For example, there would seem to be no justification for using lung cancer statistics for smokers to determine a baseline risk of lung cancer for a nonsmoking plaintiff.

⁵⁶ See *supra* note 44.

⁵⁷ This is not unlike the problem of which variables are acceptable for labor market specification in Title VII cases. See, e.g., *Wards Cove Packing Co., Inc. v. Atonio*, ___ U.S. ___, 109 S. Ct. 2115, 2117 (1989) (addressing issue of variables or statistics relevant as measures of "the pool of qualified job applicants" or "qualified labor force population").

⁵⁸ Professor Clarence Morris discussed this same problem in the context of attorneys trying to influence the finder of fact on the issue of foreseeability:

If official description of the facts of the case as formulated by the court is detailed, the accident can be called unforeseeable; if it is general, the accident can be called foreseeable. Since there is no authoritative guide to the proper amount of specificity in describing the facts, the process of holding that a loss is—or is not—foreseeable is fluid and often embarrasses attempts at accurate prediction.

CLARENCE MORRIS & C. ROBERT MORRIS, JR., *MORRIS ON TORTS* 165 (2d ed. 1980). The issue of foreseeability includes as an important factor the expected frequency of occurrence, and a factfinder's determination of this factor depends in large part on the description used to identify the events being counted.

⁵⁹ See *supra* note 44 (discussing jury role in intuiting baseline risk).

A second kind of uncertainty—measurement uncertainty—arises even in cases where appropriate variables are definable. Uncertainty can still arise in estimates of the likelihood of occurrence because of the potential for error in actually classifying particular instances. The usual means of gathering mortality statistics, for example, have well documented sources of error,⁶⁰ and the data gathered may include misclassifications of the cause of death. Scientists are therefore concerned that data-gathering methods be both valid and reliable: that is, that they actually measure what they are thought to measure, and that independent reclassification of the same cases would yield consistent results.⁶¹ Any measurement or classification error could, of course, result in error in estimates of baseline risk.

In a significant number of tort cases, expert witnesses testify as to the risk factors present in the reference situation and perhaps estimate the baseline risk itself. In the vast majority of tort cases, however, the relevant hazard variable is taken as obvious (e.g., in a wrongful death case, the relevant hazard is death). Moreover, both the identification of the reference situation and the estimation of the relative frequency of occurrence of the harm in that reference situation are often left to the trier of fact, without the aid of expert testimony. For example, jurors are often left on their own to determine the appropriate reference situation and baseline risk for an automobile accident.⁶²

Despite the traditional need for expediency, however, the fact remains that the personal experience that a judge or jury has with the plaintiff's reference situation might be rather limited. A person generally has information or informed intuitions on baseline risk only for those situations that she has experienced sufficiently often. And nonexperts may tend to be inaccurate in estimating the true likelihood of relatively rare injurious events.⁶³ Yet in most cases, the court relies on the jury's judgment and imagination, based on limited personal experience or anecdotal reports from witnesses. As a result, legally significant determinations of baseline risk are often based on a substantial degree of ignorance, whether due to a lack of personal knowledge or a lack of valid and reliable data.

⁶⁰ See LILIENTHAL & LILIENTHAL, *supra* note 51, at 67-71, 84-90.

⁶¹ See *supra* note 42.

⁶² See *supra* notes 44, 46.

⁶³ E.g., GUIDO CALABRESI, *THE COSTS OF ACCIDENTS* 55-57, 206-07 (1970); Paul Slovic, *Informing and Educating the Public About Risk*, 6 *RISK ANALYSIS* 403, 404 (1986).

B. Modeling Uncertainty

Part of what is meant by saying that a situation has inherent risk is that the circumstances and the injury are associated with each other in some regular way in the real world. An observable, regular association between the situation and the harm is usually required as evidence of a risk relationship between the two, unless the lack of observed association is explainable.⁶⁴ In order to determine baseline risk, one would look for a statistical association between the occurrence of the reference situation absent the defendant's negligence, and the occurrence of the injury. When data on incidence are available, one would look for a mathematical model that could be used to predict the likelihood of injury given the occurrence of the situation.⁶⁵

A simplified example can be constructed from the old case of *Stubbs v. City of Rochester*,⁶⁶ in which the plaintiff alleged that he had contracted typhoid fever by drinking water that had become contaminated through the negligence of the defendant. In support of his case, the plaintiff established that he had drunk water at his place of employment in the contaminated portion of the city and had subsequently become ill, that the water in that portion of the city was indeed contaminated, and that the only water he had drunk during the relevant period was city water (both at his place of employment and elsewhere, in uncontaminated portions of the city). Expert witnesses for the plaintiff testified that he probably contracted his illness from drinking the contaminated water. Statistics for a prior ten-year period confirmed that an unusually high number of typhoid fever cases had occurred in Rochester during the time when the water was contaminated.⁶⁷

What follows is an analysis of the baseline risk of typhoid fever in Mr. Stubbs's case, supplying hypothetical information where needed. Assume that Stubbs's reference situation is living in Rochester during the relevant period and drinking only city water, with at least some water coming from the contaminated portion of

⁶⁴ See *infra* part II.D (discussing causal uncertainty).

⁶⁵ Elsewhere, the author has discussed the notion of modeling uncertainty generally, using the example of regression modeling. See Walker, *supra* note 27, at 598-608. The common epidemiologic models discussed in this Article (relative risk and odds ratios) are additional examples of mathematical models that are used to relate two variables: exposure (often the independent variable) and disease incidence (the dependent variable).

⁶⁶ 124 N.E. 137 (N.Y. 1919).

⁶⁷ See *Stubbs v. City of Rochester*, 124 N.E. 137, 139-40 (N.Y. 1919).

the city. Suppose, further, that there were 15,000 full-year residents of the City of Rochester in 1910 that drank only city water, and that of these, 10,000 were in a situation similar to Stubbs (the reference situation) during the relevant time period,⁶⁸ in the sense that they drank at least some water from the contaminated portion of the city. Assume also that a total of 180 cases of typhoid fever were reported from among those full-year residents, and that 150 of these 180 cases were among members of the set of 10,000 similarly situated residents.⁶⁹ This information can be presented as in Table 1.

Incidence of Typhoid Fever; Rochester, N.Y.; August through November, 1910		
	<i>Typhoid Fever</i>	
	<i>Yes</i>	<i>No</i>
<i>Exposure Situation:</i>		
<i>Similar to Stubb's</i> <i>(Reference Situation)</i>	150	9850
<i>Similar to Stubb's,</i> <i>except No Ingestion of</i> <i>Contaminated Water</i>	30	4970

Table 1

The traditional tort concern is whether there is any increased or incremental risk between being in Stubbs's situation and contracting typhoid fever, after taking into account the background incidence of typhoid fever due to living in Rochester and drinking city water.⁷⁰ The focus here, however, is on the baseline risk itself,

⁶⁸ The "relevant time period" would be identified by reference to the nature of typhoid fever, its incubation period if any, and other epidemiologic features of the disease. See LILIENTHAL & LILIENTHAL, *supra* note 51, at 46-61.

⁶⁹ The other 30 cases of typhoid fever occurred to the 5000 full-year residents that drank water only from the uncontaminated part of the city water system.

⁷⁰ In epidemiologic terms, the "incidence" rate is the number of new cases of a disease occurring during a specified period of time, divided by the number of people exposed to the risk of developing the disease during that time. Thus, the "incidence rate is a direct estimate of the probability, or risk, of developing a disease during a specified period of time." LILIENTHAL & LILIENTHAL, *supra* note 51, at 138-39. The "prevalence" rate, by contrast, measures the total number of cases present in the population at or during a specified time. *Id.* See generally *id.* at 138-44 (discussing the incidence and prevalence rates in epidemiologic calculations).

not the increased risk over baseline. To determine the incidence that would be expected, even in the absence of the defendant's negligence in contaminating a portion of the city's water, one could consult rates of occurrence for the disease among those 5000 people in 1910 that would have been in the reference situation but for the fact that they did not drink any of the contaminated water.⁷¹ Based upon this background information, the *expected* incidence for each cell in Table 1 would be as shown in Table 2. In comparing Table 1 and Table 2, it is clear that for people in exposure situations similar to that of Stubb's, there is a difference between the expected incidence of cases and the incidence that was actually observed in 1910.

Expected Incidence of Typhoid Fever; Rochester, N.Y.; August through November, 1910		
	<i>Typhoid Fever</i>	
	<i>Yes</i>	<i>No</i>
<i>Exposure Situation:</i>		
<i>Similar to Stubb's (Reference Situation)</i>	60	9940
<i>Similar to Stubb's, except No Ingestion of Contaminated Water</i>	30	4970

Table 2

Table 3 presents the general format for a 2 X 2 table useful in evaluating the plaintiff's baseline risk when the defendant's negli-

⁷¹ In addition, or alternatively, one could consider the incidence in other years during which there was no contamination, provided other factors affecting typhoid incidence were substantially similar to the reference situation. Assume for simplicity that for the prior ten years, the incidence of typhoid fever during the same four months of the year as the outbreak in 1910 averaged sixty cases per 10,000 people—the same rate as for the 5000 residents in 1910 that did not drink contaminated water.

gent act is conceptualized as a separate risk factor.⁷² In Table 3, the values a, b, c, and d are the frequencies of cases in each cell of the 2 X 2 table. In generating this information, each instance or subject must be classified into the appropriate categories of the exposure variable⁷³ and the injury variable.

General Format for Determining Baseline Risk			
	<i>Injury</i>		<i>Totals:</i>
	<i>Yes</i>	<i>No</i>	
<i>Exposure or Characteristic:</i>			
<i>Reference Situation</i>	a	b	a + b
<i>Reference Situation, except without Defendant's Act</i>	c	d	c + d
<i>Totals:</i>	a + c	b + d	a + b + c + d

Table 3

Once the data have been assembled in this format, any statistical association between the variables can be examined. Two principal questions are whether an association exists at all, and, if so,

⁷² Sociologists and epidemiologists, although pursuing similar lines of analytical reasoning and performing comparable statistical analyses, often utilize different conventions. In constructing a 2 X 2 table, for example, sociologists often set up the table so that the dependent variable's categories are listed down the left side ("stub") of the table, while the categories of the independent variable are listed across the top ("heading") of the table. See, e.g., LOETHER & McTAVISH, *supra* note 42, at 180. Epidemiologists, on the other hand, usually list the exposure variable (the independent variable in a prospective study) down the left side of the table and the disease variable across the top of the table. See, e.g., STEVE SELVIN, *STATISTICAL ANALYSIS OF EPIDEMIOLOGIC DATA* 345 (1991); HAROLD A. KAHN & CHRISTOPHER T. SEMPOS, *STATISTICAL METHODS IN EPIDEMIOLOGY* 45-50 (1989); LILIENFELD & LILIENFELD, *supra* note 51, at 196 (Tables 8-2 and 8-3). The convention adopted here follows the approach of the epidemiologists, conceptualizing the baseline risk and the incremental risk created by the defendant as resulting from exposure factors and listing the exposure situations down the left side of the table.

⁷³ The independent variable may also be a characteristic, such as being in a specific blood group or having a certain gene. For simplicity, however, this analysis will refer simply to "exposure" to the relevant risk factors.

what the strength of the association is.⁷⁴ No association exists if there is no difference in the percentage distribution of cases under the injury variable for the categories in the exposure variable. In other words, there is complete statistical independence of the injury variable relative to the exposure variable if identical percentages appear in each cell in each column. For the format in Table 3, no association of injury categories to exposure categories would exist if percentages are computed for the rows corresponding to each of the exposure categories (e.g., percentages are computed such that the percentages for the ratios $(a/a+b)$ and $(b/a+b)$ add to 100%), and the percentages in each column are identical (e.g., the percentage for the ratio $a/a+b$ equals the percentage for $c/c+d$).

An illustration of statistical independence can be constructed by converting the expected frequencies in Table 2 into percentages as shown in Table 4. If these expected frequencies had actually occurred, there would be no evidence of statistical association between drinking that contaminated water and developing typhoid fever. By contrast, the (hypothetical) observed results presented in Table 1 do evidence a statistical association when presented in percentages, as in Table 5.

Expected Incidence of Typhoid Fever, in Percentages; Rochester, N.Y.; August through November, 1910			
	<i>Typhoid Fever</i>		
	<i>Yes</i>	<i>No</i>	<i>Totals:</i>
<i>Exposure:</i>			
<i>Similar to Stubbs's (Reference Situation)</i>	0.6%	99.4%	100%
<i>Similar to Stubbs's, Except No Ingestion of Contaminated Water</i>	0.6%	99.4%	100%

Table 4

⁷⁴ Two additional characteristics of an association become important when the variables are quantitative in nature: the direction of the association and the nature of the association. The direction of any association is determined by whether the higher values of one variable are associated with the higher values of the other variable (a positive association), or whether the higher values of one variable are associated with the lower values of the other variable (a negative association). The nature of an association may be linear or curvilinear. See LOETHER & MCTAVISH, *supra* note 42, at 193-96.

Observed Incidence of Typhoid Fever, in Percentages; Rochester, N.Y.; August through November, 1910			
	<i>Typhoid Fever</i>		
	<i>Yes</i>	<i>No</i>	<i>Totals:</i>
<i>Exposure:</i>			
<i>Similar to Stubbs's (Reference Situation)</i>	1.5%	98.5%	100%
<i>Similar to Stubbs's, except No Ingestion of Contaminated Water</i>	0.6%	99.4%	100%

Table 5

It has become common for epidemiologists to use incidence data, such as the hypothetical data in Table 5, to identify "risk factors": those exposure factors or characteristics that are associated with increased risk.⁷⁵ Once a risk factor has been identified, the strength of the statistical association between the risk factor and disease incidence can be expressed by either "relative risk" or "odds ratios."⁷⁶ Relative risk is the ratio of the incidence rate of typhoid fever for those with the risk factor (exposure to water negligently contaminated by the defendant) relative to the incidence rate for those similarly situated except for the risk factor.⁷⁷ The

⁷⁵ See LILIENFELD & LILIENFELD, *supra* note 51, at 259-60.

⁷⁶ See, e.g., MICHAEL O. FINKELSTEIN & BRUCE LEVIN, STATISTICS FOR LAWYERS 1-2, 18 (1990); KAHN & SEMPOS, *supra* note 72, at 45; LILIENFELD & LILIENFELD, *supra* note 51, at 209, 342-47; Leon Gordis, *Estimating Risk and Inferring Causality in Epidemiology*, in EPIDEMIOLOGY AND HEALTH RISK ASSESSMENT 51-52 (Leon Gordis ed., 1988).

This is not to suggest that other statistical measures, such as Guttman's Coefficient of Predictability or Goodman and Kruskal's tau-y, would not provide useful measures of, or perspectives on, strength of association between qualitative variables. See, e.g., LOETHER & McTAVISH, *supra* note 42, at 225-27. The conceptual objectives of this Article, however, would not be advanced by including a discussion of such alternative approaches.

⁷⁷ In terms of the general format presented in Table 3, *supra*, relative risk ("RR") is defined as follows:

$$RR = \frac{a/(a+b)}{c/(c+d)}$$

KAHN & SEMPOS, *supra* note 72, at 45-46. After percentages are calculated so that rows in Table 3 sum to 100% (as in Table 4), relative risk is the ratio of percentages in each column: $0.6 / 0.6 = 1.0$ (showing no statistical association) for those expected to get typhoid fever in Table 4, and $1.5 / 0.6 = 2.5$ for those with typhoid fever in Table 5.

relative risk of those in Stubbs's reference situation, compared to those in Rochester similarly situated with the sole exception of not drinking the contaminated water, is 2.5.⁷⁸ In other words, these data indicate that those persons in Stubbs's situation had a risk of typhoid fever that was 2.5 times the risk faced by those not exposed to the contaminated water.⁷⁹

An alternative measure of strength of association is the odds ratio: a comparison of the odds of contracting typhoid fever if subjected to the defendant's negligence (the reference situation) to the odds of contracting the disease if not so subjected.⁸⁰ The odds ratio of the observed data from Table 1 is 2.523.⁸¹ The odds of contracting typhoid fever were 2.523 times greater for those in Stubbs's situation than for those that did not drink the contaminated water.

The conceptual approach of this Article may be characterized as one using an epidemiologic paradigm to think of the defendant's negligent act as a risk factor with respect to the relevant type of injury, and the combination of all risk factors other than the defendant's negligent act as comprising the baseline risk. Using this terminology, the plaintiff's capability of establishing liability depends in part on whether she can establish that the defendant's act was a risk factor in the situation, incremental to the other risk factors inherent in the reference situation.⁸²

⁷⁸ The computation is: $(150/10,000) / (30/5000) = 0.015 / 0.006 = 2.5$. See *supra* note 77.

⁷⁹ Note here the critical importance of defining the reference situation as including only those persons that were similarly situated to Stubbs. It would be irrelevant—and would bias the baseline risk estimate in favor of either the plaintiff or the defendant—to include incidence data not otherwise representative of Rochester: for example, incidence data from the nation as a whole, from some foreign city, or from some other time when typhoid risk conditions in Rochester were significantly different.

⁸⁰ In terms of the general format used in Table 3, the odds ratio is defined as $(a/b)/(c/d)$. With algebraic manipulation, it can be shown that this formula has a simpler form, a ratio of cross-products from the 2 X 2 table: ad / bc . See, e.g., FINKELSTEIN & LEVIN, *supra* note 76, at 2-4; KAHN & SEMPOS, *supra* note 72, at 52; Gordis, *supra* note 76, at 52.

⁸¹ The calculation is as follows: $(150/9850) / (30/4970) = 2.523$. The calculation using the simpler form, see *supra* note 80, yields identical results: $(150)(4970)/(30)(9850) = 2.523$.

This example illustrates a general principle: if the incidence rate of injury is relatively small, then the odds ratio will closely approximate the relative risk. See FINKELSTEIN & LEVIN, *supra* note 76, at 2-3; KAHN & SEMPOS, *supra* note 72, at 47-51; LILIENTHAL & LILIENTHAL, *supra* note 51, at 209-10.

⁸² Methods for determining the magnitude of baseline risk are closely allied to methods that could be used to determine whether a defendant's negligent act created any incremental risk for the plaintiff. Insofar as baseline risk and unreasonable incremental risk are both

C. *Sampling Uncertainty*

Information about the normal incidence of harm in identifiable situations, the fundamental data for determining baseline risk, is always limited. It is limited to information about those situations and outcomes personally familiar to the judge or jury, or to information reported to them through the testimony of experts. Expert testimony is based in turn either on the expert's own experience with some number of such situations or, more often, on reports of other experts documenting statistics for such situations. Even in cases where statistics about baseline risk are available, such statistics are invariably based upon a limited number of instances. In all cases, therefore, the basis for the finder of fact's conclusions about baseline risk is a *sample*: a limited number of instances of the reference situation and hazard event relevant to the litigation.

The task is to devise techniques for estimating baseline risk on the basis of such limited information and for assessing the extent to which the limited data that happen to be available are really representative of the reference situation. Enabling such estimates and assessments is one of the objectives of the statistical theory of sampling. This theory is most straightforward for sampling performed in a random manner (e.g., "simple random sampling," which is performed in such a way that each possible sample of the size drawn has an equal chance of being drawn⁸³). When the available sample is a random sample, then one can employ statistical sampling theory to estimate incidence rates and baseline risk with considerable confidence.

The reasoning behind such an estimate is hypothetical in form. If an hypothesis is made that the baseline risk for typhoid fever for Rochester residents in 1910 was 0.6%, as in Table 4, and a randomly selected sample of full-year residents that did not drink the contaminated water showed a much higher or lower percentage of fever cases, it would suggest that the original hypothesis was false. A sampling result is said to be "statistically significant" with respect to some hypothesized value for the population, if it would be very unlikely that such a sampling result would have been drawn if the hypothesis value were true. If the sampling results are "sta-

risk, it is not surprising that similar evidentiary techniques could be used to establish both. The discussion in this Article, although focusing on techniques for determining the magnitude of baseline risk, also lays a conceptual foundation for undertaking an analysis of unreasonable risk.

⁸³ See generally Walker, *supra* note 27, at 588-98.

tistically significant," then one can conclude with considerable confidence that the hypothesis of 0.6% for the reference situation was *probably* wrong and can "reject" that hypothesis as *unlikely* to be true.⁸⁴

One technique for conveying information about the statistical significance of a sample is the "confidence interval." A confidence interval is a range of possible true values in the population. For example, the percentage of typhoid fever cases among full-year Rochester residents that did not drink contaminated water might be characterized as "between 0.3% and 0.9%," or "0.3% - 0.9%." If this range is a confidence interval, then all values *within* the confidence interval cannot be rejected on the basis of the sample (that is, the sample is not statistically significant for hypothesis values within the confidence interval), but all values *outside* the interval may be rejected (the sample results are statistically significant for those hypothesis values).⁸⁵ A "95% confidence interval" is a range of hypothesis values that should not be rejected on the basis of the sample results, provided one is prepared to be wrong in as many as 5% of the cases (i.e., one is willing to accept that perhaps 1 time in 20 the confidence interval would not contain the true value).⁸⁶ Confidence intervals provide a convenient way for reporting which hypothesis values are rejectable, and which are not, given a sample.⁸⁷

When data are gathered on a specific group of people, one is usually dealing with a sample drawn from the population. If, for example, one treats the 5000 residents of Rochester as a simple random sample of persons similarly situated to Stubbs except for the absence of drinking the contaminated water, then based upon the observed percentage of 0.6% in that sample,⁸⁸ one can derive

⁸⁴ For a discussion of the scientific convention adopting "less than 0.05" as the sampling probability that is so low that it is used to define "statistical significance," see Walker, *supra* note 27, at 593-98. Cf. *Richardson v. Richardson-Merrell, Inc.*, 857 F.2d 823, 830-31 (D.C. Cir. 1988) (affirming lower court's grant of judgment n.o.v. in defendant's favor in Bendectin case because expert's opinion lacked an adequate basis; expert "acknowledged the necessity of a statistically significant association between the drug and its effect in human populations," but no published studies had concluded that there was such an association).

⁸⁵ JACOB COHEN & PATRICIA COHEN, *APPLIED MULTIPLE REGRESSION/CORRELATION ANALYSIS FOR THE BEHAVIORAL SCIENCES* 63 (2d ed. 1983); WILLIAM L. HAYS, *STATISTICS* 206-09, 235-41, 277-78 (4th ed. 1988).

⁸⁶ COHEN & COHEN, *supra* note 85, at 63; HAYS, *supra* note 85, at 206, 236, 278.

⁸⁷ COHEN & COHEN, *supra* note 85, at 63; HAYS, *supra* note 85, at 278.

⁸⁸ See *supra* Table 5.

a 95% confidence interval of plus or minus approximately 0.2% around that observed percentage.⁸⁹ Even if the true incidence in the population were 0.6%, one could still expect to draw, perhaps nineteen times out of twenty, a random sample of 5000 people with as few typhoid cases as twenty (5000 x 0.4%) or as many cases as forty (5000 x 0.8%). If this sample of 5000 is used to derive an estimate of baseline risk for Stubbs's reference situation, and one concludes that that true baseline risk is probably within the confidence interval of 0.4% - 0.8%, then one can calculate that in a group of 10,000 (the number of people in Stubbs's reference situation) as many as forty to eighty cases are very likely due to baseline risk.

Part II.B. of this Article introduced relative risk and the odds ratio as measures of the strength of the statistical association. Confidence intervals can also be computed for these measures, providing a measure of the sampling uncertainty inherent in these risk or odds statistics. Using accepted methods for computing confidence intervals of relative risks,⁹⁰ the 95% confidence limits around the relative risk of 2.5 found in Table 1 would be approximately 1.69 and 3.69.⁹¹ The relative risk of 2.5 is therefore significantly different (in a statistical sense) from 1.0 (zero increase in relative risk). One can reject with considerable confidence the hypothesis that those in Stubbs's reference situation were no more

⁸⁹ From a population with a proportion (incidence rate of disease) of 0.006 ("P"), the expected value of the proportion ("p") in the sample (of size $n = 5000$) is also 0.006, with a standard error (unit dispersion) equal to

$$\sqrt{\frac{P(1-P)}{n}} = \sqrt{\frac{(0.006)(0.994)}{5000}} = 0.001.$$

See HAYS, *supra* note 85, at 240; LILIENFELD & LILIENFELD, *supra* note 51, at 332-36. With $n = 5000$, and the proportion in the population $P = 0.006$ (0.6%), the normal distribution provides a reasonable form for the sampling distribution of the proportion. See HAYS, *supra* note 85, at 240; LILIENFELD & LILIENFELD, *supra* note 51, at 333. The 95% confidence interval around 0.006 is therefore provided by plus or minus $1.96 \times 0.001 = 0.002$ (approximately). See *id.* at 333-36; HAYS, *supra* note 85, at 240-41. This estimate for the 95% confidence interval, while adequate for this discussion, is inappropriately symmetrical. For an incidence rate this small (0.006), a confidence interval based on the Poisson distribution would be approximately 0.4%-0.86%. See LILIENFELD & LILIENFELD, *supra* note 51, at 336-38.

⁹⁰ See LILIENFELD & LILIENFELD, *supra* note 51, at 344-46; D. Katz et al., *Obtaining Confidence Intervals for the Risk Ratio in Cohort Studies*, in 34 *BIOMETRICS* 469 (1978); KAHN & SEMPOS, *supra* note 72, at 62-63.

⁹¹ The calculation, which utilizes the natural logarithm transform of the relative risk and an estimate of the variance for this transform, is as follows. The relative risk (RR) is

at risk for typhoid fever than those residents of Rochester at the time that did not drink the contaminated water.⁹²

If quantitative data on baseline risk are available,⁹³ such that confidence intervals can be derived for relative risk or the odds

2.5, and the natural logarithm of 2.5 ($\ln 2.5$) is 0.916. One estimate of the variance of $\ln RR$, using the notation of Table 3, is given by the formula:

$$\frac{1}{(a + 1/2)} + \frac{1}{(b + 1/2)} + \frac{1}{(c + 1/2)} + \frac{1}{(d + 1/2)}$$

The calculation of the estimated variance for the data in Table 1 is:

$$\begin{aligned} \text{est. var.} &= \frac{1}{150.5} + \frac{1}{9850.5} + \frac{1}{30.5} + \frac{1}{4970.5} \\ &= 0.0066 + 0.0001 + 0.0328 + 0.0002, \\ &= 0.0397. \end{aligned}$$

The estimated standard error of $\ln RR$ is the square root of the variance:

$$\text{est. S.E.} (\ln RR) = \sqrt{0.0397} = 0.199.$$

The 95% confidence interval ($CI_{95\%}$) in natural logarithms is provided by:

$$\begin{aligned} CI_{95\%} (\ln RR) &= (\ln RR) \pm (1.96 \times \text{S.E.} (\ln RR)), \\ &= 0.916 \pm (1.96 \times 0.199), \\ &= 0.916 \pm 0.39. \end{aligned}$$

The confidence limits in logarithms are thus 0.526 and 1.306. Finally, transforming these two limits back from natural logarithms provides the approximate 95% confidence interval in units of relative risk:

$$CI_{95\%} RR = 1.69 \text{ to } 3.69.$$

⁹² See LILIENFELD & LILIENFELD, *supra* note 51, at 344. Using Woolf's method for calculating confidence intervals for the odds ratio, see KAHN & SEMPOS, *supra* note 72, at 56; SELVIN, *supra* note 72, at 344-47, the 95% confidence limits for the odds ratio of 2.523 for the data in Table 1 are approximately 1.7 and 3.74. Woolf's method utilizes the natural logarithm transform of the estimated odds ratio, together with a formula for the estimated standard error of this transform, as follows:

$$\begin{aligned} OR &= 2.523, \\ \ln OR &= 0.9254, \\ \text{est. S.E.} (\ln OR) &= \sqrt{\frac{1}{a} + \frac{1}{b} + \frac{1}{c} + \frac{1}{d}}, \\ &= \sqrt{0.0403} \\ &= 0.2007, \\ CI_{95\%} (\ln OR) &= 0.9254 \pm (1.96 \times 0.2007), \\ &= 0.9254 \pm 0.393. \end{aligned}$$

The 95% confidence limits for the odds ratio (transformed back from the natural logarithms) are therefore approximately 1.7 and 3.74. These confidence limits closely approximate those for the relative risk and also show statistical significance relative to the hypothesis that there was no incremental risk for being in Stubbs's situation.

⁹³ A desirable characteristic for an adequate concept of baseline risk is that no

ratio, two questions arise: How much sampling uncertainty should be tolerated in tort litigation? And what is the minimal degree of confidence on which a jury should be able to rely? Simply because a scientific convention exists to accept 95% confidence as the "bright line" of statistical significance does not mean that tort litigation should automatically require equal confidence in associations before a jury is entitled to find a value for baseline risk.⁹⁴ This is too broad a problem, however, to try to resolve at this point. The objective here is simply to understand the kinds of uncertainty inherent in any determination of baseline risk, and thus reach a better appreciation of the nature of the concept.

D. Causal Uncertainty

The causal complexity inherent in the kind of situation increasingly dealt with in torts introduces a potential for causal error, in addition to conceptual, measurement, modeling, and sampling error.⁹⁵ Tort claims may involve situations in which the baseline risks result from combinations of environmental toxins, pharmaceutical products, genetic or other health characteristics, or complications with particular medical operations. Such reference situations may present complicated causal systems and result in tremendous uncertainty as to causal interactions. Causal uncertainty may arise because causal factors are numerous, not readily observable by the casual observer, or interactive in their effects.⁹⁶ The casual observer

conceptual change is needed to accommodate the transition of legal decision making from a qualitative mode to a quantitative mode. As more statistical information about accident situations becomes available, the law should not have to undergo a redefinition of concepts in order to accommodate it. The concept of baseline risk proposed here is designed to fit into such a comprehensive framework by providing a single conceptual bridge between more traditional cases (e.g., qualitatively evaluated automobile collision cases) and cases where quantitative scientific information on risk is available.

⁹⁴ Although this question arises naturally in the context of calculating confidence intervals, it is really one aspect of the broader issue of how much scientific uncertainty should be acceptable in tort litigation (i.e., how much conceptual and measurement uncertainty, modeling, sampling, and causal uncertainty).

⁹⁵ See generally Walker, *supra* note 27, at 608-18.

⁹⁶ In the automobile collision case where the defendant negligently loses control of his car, crosses the center line, and collides with the plaintiff's car, the causal effect of the defendant's act so dominates the normal risks inherent in the situation that one has little difficulty deciding that the baseline risk is very low, and that the defendant's act "caused" the injury. On the other hand, in the case of a medical misdiagnosis or an increased exposure to a carcinogen, the determination of the baseline risk may become significantly more complicated. Conceptual techniques are needed for distinguishing causal contributions in such cases.

may notice that event A occurred, followed by event B. A more careful observer may note only that event B sometimes follows event A in a given situation, and sometimes not. The observable regularity expected from a simple causal relationship might not ever appear.⁹⁷

This subpart discusses several problems associated with determining causal relationships within causally complex situations. First, in order to refine the understanding of causal uncertainty and the implications for baseline risk, it discusses several experimental design principles and statistical techniques that assist in deriving causal conclusions from statistical associations. Then the subpart analyzes a fundamental epistemological and proof problem referred to as the "baseline risk paradox."

1. *The Nature of Causal Uncertainty*

Some concept of causation is implicit in the concept of risk: risk involves the chance that harm will *result* from a situation, with the presupposition that some underlying causal connections are bringing about the harm, even if all of the causal elements are not identifiable or their interactive effects are not traceable in detail.⁹⁸ Although the mechanics of cancer may not be understood, it is assumed that the reason cancer poses a risk of death is that a causal process is underway in the body that often brings about death in the normal course of things. Cancer poses a risk of death because some process manifesting as "cancer" *causes* death.

To the extent that baseline risk exists in a reference situation, therefore, one assumes that there must be a causal relationship between some causal factors (other than the defendant's negligence) in the type of situation presented and the type of injury suffered by the plaintiff.⁹⁹ Baseline risk presupposes a causal nexus between

⁹⁷ Uncertainty as to the underlying and unobserved causal system can remain even if the sample size (number of observed situations) is increased dramatically. The lack of observed correlation may not be an artifact of sampling error at all. The statistical treatments of sampling error discussed in the previous section do not address the problem of causal error.

⁹⁸ In tort litigation, the current theories of liability are predominantly causal: there is no liability on the part of the defendant unless the defendant's acts are causally related to the plaintiff's injuries.

⁹⁹ A good example of a combination of baseline risk and defendant-created risk is smoking cigarettes and exposure to asbestos as combined risk factors for illness. See, e.g., Irving V. Selikoff & E. Coyer Hammand, *Asbestos and Smoking*, 242 JAMA 458 (1979). The relative contributions of smoking and asbestos exposure to illness have had increasing

factors at work in the situation presented and the plaintiff's type of injury. In part, therefore, the evidence for baseline risk often includes evidence of this causal nexus, evidence of these causal factors.

Although for convenience the causal relationship can be described as running from the "situation" to the injury, the term "situation" is intended to refer to that set of factors or agents that were present in the plaintiff's circumstances and which could cause (together or in isolation) the type of injury in question. For example, in the *Stubbs* case, the baseline risk of typhoid fever was thought to be the result of a large number of possible causal paths, including the consumption of raw fruits and vegetables, shell fish, and milk, or infection through house flies or other persons already infected.¹⁰⁰ Scientists have developed various techniques for studying such complex systems of causal factors.

Statistically significant associations can be created between two variables either because they are causally related directly to each other (one causing the other), or because some other factor has a causal influence on both variables.¹⁰¹ A symptom might be caused by the prescription drug that has been ingested, or by the underlying disease for which the drug has been prescribed, or by some condition totally unrelated to that drug or that disease. It is only in well-designed clinical studies, where a sufficiently large number of subjects are randomly assigned to the treatment and control groups, and the subsequent histories of the subjects are adequately studied, that the scientific ideal of a study design for isolating specific causal actions is approached.¹⁰² Daily life makes people

importance in the massive asbestos litigation. See, e.g., *Brisboy v. Fibreboard Corp.*, 418 N.W.2d 650 (Mich. 1988) (lung cancer); *Martin v. Owens-Corning Fiberglas Corp.*, 528 A.2d 947 (Pa. 1987) (asbestosis).

¹⁰⁰ See *Stubbs*, 124 N.E. at 138.

A parallel can be made to gambling. In a given throw of a pair of dice, the risk of losing can be calculated as a single value, using combinatorial methods from probability theory, although there are numerous actual events (pairs of outcomes) that together account for the total risk. Several aspects of the gambling example make it relatively simplistic, however. Only one of those events (throws) will actually bring about the loss in the particular case, whereas in tort cases an infection might actually be caused by multiple agents. Moreover, in the case of gambling, the process of deriving a combined risk is usually helped by the fact that each die throw is independent of any other.

¹⁰¹ Walker, *supra* note 27, at 613.

¹⁰² Retrospective or cross-sectional studies use design methods and statistical control techniques to approximate this ideal study design, but such approaches have corresponding methodological difficulties to overcome. See generally LILIENFELD & LILIENFELD, *supra* note 51, at 194-218.

unfortunately familiar with the hunt for the elusive cause of a recurring bodily ailment (a hunt often complicated by the causal influence of psychological factors) and aware of the dangers of assuming that *post hoc ergo propter hoc*.

The rebuttal argument of defendants when significant baseline risk exists is often of the form that a temporal, or even statistical, relationship between the defendant's acts and the plaintiff's injury is coincidental, and that the real cause is something else in the situation. In other words, once the plaintiff has produced sufficient evidence of negligence and proximate cause to get her case to the jury, the defendant has an interest in establishing the existence of a significant baseline risk (relative to the incremental risk allegedly created by the defendant), and the plaintiff has an interest in minimizing the magnitude of baseline risk. One task of the trier of fact is to decide the issue of causation as between the defendant-created unreasonable risk and the baseline risk.¹⁰³ This task presents the problem of the "baseline risk paradox."

2. The "Baseline Risk Paradox"

In *Stubbs*,¹⁰⁴ the plaintiff presented evidence to show that he had drunk water from a contaminated portion of the city water system, that he had subsequently contracted typhoid fever, and that fifty-eight others had drunk water from the same vicinity and had become ill with the same disease. Although *Stubbs* had also drunk water from uncontaminated portions of the city, the only water he had drunk during the relevant period was city water. His testimony was supported by expert opinion that he had been made ill by drinking the contaminated water. Despite such evidence, the trial court granted a motion for nonsuit at the close of the plaintiff's case; the appellate division affirmed by a three-two vote; and the court of appeals reversed in a narrow four-three vote. The defendant had argued that the plaintiff had failed to establish "that his illness was not due to any other cause to which typhoid fever may be attributed for which defendant is not liable."¹⁰⁵ The

¹⁰³ The formulation of the standard of proof as "more likely than not" leads to a companion formulation: the task of the jury on the issue of cause in fact is to decide whether the evidence tips in the direction of the defendant's negligence or in the direction of the set of all other factors present in the reference situation. The jury is to decide between the defendant's negligent act and "everything else" that might have caused the injury.

¹⁰⁴ 124 N.E. 137; see also *supra* text accompanying notes 66-69.

¹⁰⁵ *Stubbs*, 124 N.E. at 138.

defendant had offered evidence that there were many ways of contracting typhoid fever.

Perhaps what troubled the numerous judges hearing this case at various stages was what this Article will call the "baseline risk paradox." Simply stated, the existence of a residual non-negligible baseline risk for the injury suffered by the plaintiff requires that the causal determination in the case be made without the aid of any deciding qualitative factors. Conceptually, this paradox is the root of both the "indeterminate plaintiff" problem¹⁰⁶ and the "lost chance" problem.¹⁰⁷ The practical question for the court is what burden of production of evidence to place on the plaintiff, before allowing the jury to guess about the actual causation in the particular case at bar and entering judgment on a verdict for the plaintiff.

In Stubbs's lawsuit, as the plaintiff added public health statistics to the medical expert testimony and the anecdotal lay testi-

¹⁰⁶ The "indeterminate plaintiff" problem arises when the defendant's negligence injures some number of individuals, but those specific individuals cannot be identified within a larger set of persons with the same injury. See Richard Delgado, *Beyond Sindell: Relaxation of Cause-in-Fact Rules for Indeterminate Plaintiffs*, 70 CAL. L. REV. 881, 882-86 (1982). The question of how to resolve liability in such suits has received considerable attention. See, e.g., *In re "Agent Orange" Prod. Liab. Litig.*, 597 F. Supp. 740, 833-43 (E.D.N.Y. 1984), *aff'd*, 818 F.2d 145 (2d Cir. 1987), *cert. denied*, 484 U.S. 1004 (1988); PETER H. SCHUCK, *AGENT ORANGE ON TRIAL: MASS TOXIC DISASTERS IN THE COURTS* 181-91, 255-76 (1987); Bert Black & David E. Lilienfeld, *Epidemiologic Proof in Toxic Tort Litigation*, 52 FORDHAM L. REVIEW 732, 767-69, 782-84 (1984); Delgado, *supra*; Michael Dore, *A Commentary on the Use of Epidemiological Evidence in Demonstrating Cause-in-Fact*, 7 HARV. ENVTL. L. REV. 429 (1983); Steve Gold, *Causation in Toxic Torts: Burdens of Proof, Standards of Persuasion, and Statistical Evidence*, 96 YALE L.J. 376 (1986); Kristine L. Hall & Ellen K. Silbergeld, *Reappraising Epidemiology: A Response to Mr. Dore*, 7 HARV. ENVTL. L. REV. 441 (1983); David Rosenberg, *The Causal Connection in Mass Exposure Cases: A "Public Law" Vision of the Tort System*, 97 HARV. L. REV. 849 (1984); Paul Sherman, *Agent Orange and the Problem of the Indeterminate Plaintiff*, 52 BROOK. L. REV. 369 (1986); Mary Carter Andrews, Note, *Proof of Cancer Causation in Toxic Waste Litigation: The Case of Determinacy Versus Indeterminacy*, 61 S. CAL. L. REV. 2075, 2077, 2098, 2104-10 (1988) (restricting discussion of "indeterminate plaintiffs" to those having no diagnosable signs of disease at the time of suit).

This Article is not intended to resolve the debate, which involves the appropriate judicial use of causation rules and issues of equity and fairness. This Article is limited, rather, to the perspective of baseline risk. It is worth noting, however, that the conceptual roots of the indeterminate plaintiff problem lie in the baseline risk paradox, and that the problem is not limited to a few peculiar types of cases characterized by certain kinds of causation proof. It is an instance of a more generic problem that occurs whenever there remains residual baseline risk after whatever evidence that is available has been taken into account.

¹⁰⁷ The "lost chance" problem is whether or when to allow a plaintiff to get to a jury if the baseline risk (e.g., of dying from a disease even if it had not been negligently diagnosed or treated) is greater than 50 percent. See *supra* note 13.

mony, he in fact established that of the hundreds of cases of typhoid fever in Rochester over the years, a large number had occurred in the absence of the negligent water contamination at issue in his case. There was at that time a significant baseline risk of typhoid fever from living in Rochester, quite apart from the water contamination incident of 1910. What is most reasonable to conclude, on the basis of all the evidence, is that of the 150 cases of typhoid fever that appeared during the relevant months of 1910, some substantial but indefinite number of cases were due to causes other than the contaminated water.

Assuming that among those 150 cases with exposures similar to Stubbs's, the contaminated water caused a statistically significant increase in the number of typhoid fever cases, yet some baseline number of cases occurred that were not caused by the contaminated water, the problem is determining into which category Mr. Stubbs fell. It can be presumed that there was no additional, unreported evidence that placed Mr. Stubbs in the defendant-caused category and not in the baseline category, for if there had been such evidence it surely would have been reported in the court's opinion. But more important is the point that, even if there had been such evidence, it would not obviate the problem unless the additional information succeeded in placing Mr. Stubbs in a subgroup of cases having *no* residual baseline risk (that is, *all* such cases were caused by the defendant's negligent act). As long as baseline risk remains, the problem remains: How is one to decide, nonarbitrarily, whether the particular plaintiff's case is a defendant-caused case or a baseline case?

This is not a problem peculiar to Stubbs's case, nor one peculiar to infectious diseases. In most cases of illness or injury with multiple possible causes, at some point the etiology of the particular case is not identifiable in any determinate way. At some level of medical analysis, the number of distinguishing characteristics present in the particular case is exhausted, and if some baseline risk still remains, the decision whether to place the particular case into the defendant-caused category or the baseline risk category would appear to be fundamentally arbitrary. The paradox is that, no matter how many distinguishing characteristics are taken into account, if baseline risk remains after the new characteristic is factored into the analysis, then the arbitrariness is not eliminated.

It might be objected that categorizing a specific case as either defendant-caused or baseline on the basis of *probabilities* is not "arbitrary." If one says that the baseline subcategory out of the

150 Stubbs-similar cases probably consists of about sixty cases,¹⁰⁸ leaving about ninety cases probably caused by the defendant, then placing Stubbs in the ninety-member group cannot be called "arbitrary." Several considerations, however, render such an objection problematic. First, by hypothesis, the 150 cases are alike in all relevant risk factors, so far as can be determined, and no winnowing or distinguishing characteristics exists.¹⁰⁹ Thus, if one were to try to decide *which* ninety out of the 150 cases were *the* defendant-caused cases, there would be no distinguishing characteristics to provide a decisional basis.

Second, if one believes that causal sequences are real and definite, then Stubbs's illness either was caused by bacillus ingested with defendant's water or it was not.¹¹⁰ Any probability statements would seem to be about human knowledge (or ignorance) about the actual causal sequence in Stubbs's case, or about some idealized thought experiment, but not about the specific causal sequence itself.¹¹¹ Which individual case is in which category is not known,

¹⁰⁸ This illustration uses the expected number of 60 as the estimate of baseline risk, in order to make what appears to be a stronger argument for the plaintiff. In practice one should take into account sampling uncertainty, derive a 95% confidence interval of ± 20 , and conclude with conventional confidence that it is very unlikely that less than 40 or more than 80 cases are due to baseline risk. See *supra* text accompanying notes 85-89.

¹⁰⁹ By definition, the baseline risk takes into account only risk factors relevant to the plaintiff's situation and case, see *supra* text accompanying notes 38-41; notes 55, 82. Moreover, the paradox only arises when there is *residual* baseline risk (i.e., risk remaining once all available distinguishing characteristics have been taken into account).

¹¹⁰ In Stubbs's case, his illness may also have resulted from the combination of bacilli taken in from multiple sources, including the defendant's contaminated water. The possibility of such cumulative effects does not remove the paradox and is a further complication that need not divert this discussion.

¹¹¹ This is very much unlike those situations postulated in probability theory that assume equiprobable, elementary events (such as the toss of a fair coin, the roll of a fair die, or the deal of a fair and randomly distributed deck of cards). In those situations, the probability model is valid because the causal mechanism producing the elementary events is adequately understood—as when the coin or die is determined or assumed to be "fair." But in the *Stubbs* case, the uncertainty is about the causal system at work.

Consider the following analogy. Two persons make a sizable wager and flip a coin, which lands "heads." Was the result due to pure chance or due to one party's manipulation of a biased coin? The answer depends, of course, on what causal system was at work producing the result. Rehearsing probability theorems about projected outcomes is in itself irrelevant. Those models do not apply *unless* the coin was *in fact* a fair coin. Those theorems might suggest a testing protocol to determine whether the coin and its manner of being tossed produce unbiased results in the long run. But it should be clear that probability theory alone will not retrospectively solve the problem posed.

Similarly, the relative percentages of cases falling in each category should be irrelevant to determining whether Stubbs himself fell into one category or the other. Those percentages would be relevant only if Stubbs were drawn *randomly* from the 150 cases, and the issue

although very good reason exists to conclude that *if one could* find out, one would probably find about ninety of the cases in the defendant-caused category.

Finally, if damages were to be awarded in all 150 cases, thereby treating similar cases similarly, about sixty of those decisions would probably be wrong—but no one knows *which* sixty. Although 6/15 (60/150) may be the *rate of error in the long run* if *all* the similar cases were classified as defendant-caused cases, still it is difficult to jump from that insight to a conclusion of correctness about any single, individual case.¹¹² Of course, there may be *policy reasons* to favor systematically erring on the side of the plaintiff. Such might be the case when the defendant was negligent and the plaintiff was blameless, the defendant has a greater capacity than the plaintiff to spread the costs of the accident, and so forth. But this should not obscure the paradox that, in any particular case, despite any amount of scientific information directly on point, the existence of residual baseline risk renders any categorical decision on causation epistemologically arbitrary.¹¹³

The courts have tended to obscure this paradox in several ways. First, when expert testimony is required, the courts impose on the expert witness the expectation of making the arbitrary decision and place the burden of producing such a witness on the plaintiff. If

were the probability associated with that draw. It is the random draw that is the "causal mechanism" that makes the percentages relevant by *conferring upon* Stubbs (and each other case) an *equal probability of being drawn*. But the issue in the litigation is *not* what Stubbs's probability would be if he were drawn at random from a group of 150 cases. The question is *which causal mechanism* actually made Stubbs ill: a baseline mechanism or the defendant's negligence. Deciding the latter issue on the basis of the relative percentages is as unreasonable and irrelevant as deciding that a losing hand of poker must have been the result of a fair deal because the odds are in favor of being dealt such a hand if the deal *had* been fair. Without an inspection of the deck, the card preparation, and the dealing process, one cannot decide whether the dealer or "fate" caused a *particular* loss. Cf. Gold, *supra* note 106, at 390 n.72 (explaining that causation in specific case, although unknowable, is in fact "true-or false"; either the individual's disease is a background case or it was actually caused by exposure to a toxic material); Rosenberg, *supra* note 106, at 869-70 (stating that the judicial desire for "particularistic" evidence of causation in mass exposure cases is ultimately misguided because no such evidence can be produced).

¹¹² See *supra* note 111.

¹¹³ Indeed, one could argue (although this Article will not pursue the argument) that the acceptance of the baseline risk paradox should free tort law from the pretense of needing to require cause-in-fact as a necessary element of liability and should allow the courts to press forward with fashioning a law that is fair and efficient. Cf. *Hymowitz v. Eli Lilly & Co.*, 539 N.E.2d 1069, 1073-78 (N.Y.) (disallowing defendants in DES case from exculpating themselves on the basis of no cause in fact of particular plaintiff's injury, once product defectiveness, generic causation, and national market share are demonstrated), *cert. denied*, 493 U.S. 944 (1989).

the plaintiff fails to produce an expert witness that will testify that, in her expert opinion, the plaintiff's case probably is in the defendant-caused category, then the court will probably rule that the jury is being asked to "speculate" impermissibly, with the result that the plaintiff will lose as a matter of law.¹¹⁴ If the plaintiff is successful in obtaining such expert testimony, then the jury gets to hear the case, and the substantive rationale for the ultimate decision is shrouded behind the jury verdict. Although experts can reduce or eliminate baseline risk by taking into account causal factors present in or absent from the plaintiff's reference situation, they also are often faced with the need to reach an arbitrary decision in the face of residual baseline risk. Experts cannot make knowledge out of nothing, even though, like people in general, they are not always adverse to making opinions out of nothing.

Second, courts have obscured the significance of the baseline risk paradox by characterizing the difference between having and not having such expert testimony as the difference between not speculating and speculating. It would be much less misleading to describe the difference as a matter of who is speculating and the level of speculation. When no expert testimony is available, the jury is forced to engage in the speculation alone, and the speculation is on the level of the uninformed nonexpert. Little or no guidance is available to the jury concerning what factors are possible causes and concerning the estimated number of cases falling into the baseline category. When expert testimony is available, on the other hand, the jury may receive guidance about the state of the art in the relevant scientific area, about which factors are thought to be causally relevant and which are not, and about the baseline incidence of the relevant injury in similar situations.

There are undoubtedly good policy reasons for placing a burden of production of expert testimony on the plaintiff, in the interest of forcing at least one party to place such information before the jury. But the rationale should not be that such experts can routinely get "to the bottom of things." Rather, whenever residual baseline risk exists, the expert cannot determine whether the particular case at bar falls into the baseline category or not.¹¹⁵ The requirement

¹¹⁴ *E.g.*, *Cornfeldt v. Tongen*, 295 N.W.2d 638, 640 (Minn. 1980); *see Hanselmann v. McCardle*, 267 S.E.2d 531 (S.C. 1980).

¹¹⁵ Some courts have been refreshingly candid about the judicial recognition that scientific experts speculate, even when the court may be perplexed about viable alternatives. In *Herskovits*, 664 P.2d 474, the plaintiff was unable to oppose a motion for summary

that the plaintiff produce expert testimony as part of her prima facie case *may* succeed in eliminating or at least narrowing the scope of the resulting speculation, but if residual baseline risk remains, then the result is *both* expert and jury speculation, *not* the *elimination* of speculation.

Third, courts have obscured the paradox by invoking the probabilistic standard of proof traditional in torts. Because the standard of proof is the "preponderance of the evidence," or "more likely than not," courts have tended to regard the relative size of the defendant-caused category to the baseline category as critical to deciding whether improper speculation is occurring. If the number of estimated baseline risk cases is less than 50% of the total cases (that is, the defendant-caused cases outnumber the baseline risk cases), it is concluded that a jury could reasonably find that, "more likely than not," the plaintiff's case falls into the defendant-caused category.¹¹⁶ If, however, the baseline risk is greater than 50%, the courts wonder how any reasonable jury could find that plaintiff's case is not in the baseline category.¹¹⁷ Thus, the legal significance of the baseline risk paradox has been obscured further by the notion that when the defendant-caused cases outnumber the baseline risk cases, the plaintiff should clearly be allowed to get a jury determination.

This approach to the paradox, however, is misleading. It is fallacious, as previously noted,¹¹⁸ to suggest that the relative num-

judgment by producing expert testimony that the misdiagnosis "probably" or "more likely than not" caused her husband's death. In reversing the trial court's grant of summary judgment against the plaintiff, the Washington Supreme Court stated:

Where percentage probabilities and decreased probabilities are submitted into evidence, there is simply no danger of speculation on the part of the jury.

More speculation is involved in requiring the medical expert to testify as to what would have happened had the defendant not been negligent.

Herskovits, 664 P.2d at 478. In this quotation, the phrase "what would have happened had the defendant not been negligent" is a reference, in part, to what this Article has defined as baseline risk.

¹¹⁶ See, e.g., *Harvey v. Silber*, 2 N.W.2d 483, 488 (Mich. 1942) (approving charge to jury that plaintiff need only establish by a preponderance of the evidence that surgery "would with reasonable probability have saved his life"); *Hamil v. Bashline*, 392 A.2d 1280, 1283 (Pa. 1978) (containing expert testimony that decedent would have had 75% chance of survival with proper treatment).

¹¹⁷ See, e.g., *Cooper v. Sisters of Charity, Inc.*, 272 N.E.2d 97, 104 (Ohio 1971) (holding in wrongful death action, proximate cause is issue for jury "only if there is sufficient evidence showing that with proper diagnosis, treatment, and surgery the patient probably would have survived," where "probably" means "more likely than not" or "more than 50%" expectation of survival); see also *King*, *supra* note 13.

¹¹⁸ See *supra* note 111.

ber of defendant-caused and baseline risk cases either creates or resolves the paradox.¹¹⁹ Even when statistical data and expert testimony are available, the baseline risk paradox can arise because knowledge is incomplete, because it is not known *which* causal factors brought about the *particular* plaintiff's injuries. There exists an indeterminacy about whether the particular plaintiff's injury was caused by the defendant's negligent act because the causal systems at work in the plaintiff's particular case are not understood.

Mr. Stubbs's case of typhoid fever was either caused by the drinking of the water negligently contaminated by the defendant, by some other, unrelated cause, or perhaps by some combination of the defendant's act and the other causes. The ignorance, however, over what the actual causes were in Stubbs's situation is not dispelled by noting the relative percentages of cases in each category, or by assuming that the causal system actually at work is accurately modeled by a random drawing. Such issues obviously reach further into the realms of causation and probability than this Article can venture in detail. It must be sufficient here to note the paradox. No matter what level of scientific causal analysis is achieved, the epistemologically arbitrary nature of the decision to categorize the particular plaintiff's injury into the baseline risk category or the defendant-created risk category is not eliminated so long as a non-negligible baseline risk remains at that level of analysis.

III. JUDICIAL USE OF THE CONCEPT OF BASELINE RISK

With a refined understanding of the concept of baseline risk, of the kinds of scientific evidence relevant to determining baseline risk, and of the kinds of uncertainty associated with such a determination, this Article now turns to a discussion of the uses to

¹¹⁹ Even if only about thirty cases out of 150 are baseline risk cases, it is still not known which causal factors were in fact responsible for the plaintiff's illness. See *Falcon v. Memorial Hosp.*, 462 N.W.2d 44, 47 (Mich. 1990) ("To say that a patient would have had a ninety-nine percent opportunity of survival if given proper treatment, does not mean that the physician's negligence was the cause in fact if the patient would have been among the unfortunate one percent who would have died."). This issue is not resolved by pointing out that if we *randomly* drew only one case from the 150, we would probably draw a defendant-caused one. It would make far more sense to be moved in such a case simply by considerations of fairness. If defendant-caused cases outnumber baseline cases, it may seem fairer to make the defendant compensate all plaintiffs that sue, rather than let the defendant escape all liability.

which the concept can fruitfully be put. The discussion here can be only preliminary in nature because, as with most tools, concepts often turn out to have many uses beyond those envisioned by those that designed the concept. The intent here is simply to suggest the probable usefulness of the concept by pointing the way toward a number of uses that already can be anticipated.

This Part of the Article is divided into three subparts. The first discusses the relevance of baseline risk to various elements of traditional tort causes of action. The second examines burdens of production with respect to baseline risk. It also addresses the question of minimally sufficient evidence for establishing baseline risk and explores the potential for resolving this question on a motion for summary judgment or directed verdict. The third subpart discusses certain considerations that may affect the appropriate allocation of the burden of persuasion with respect to baseline risk.

A. Relevance of Baseline Risk

1. Negligence

Throughout Parts I and II, the example of a negligence cause of action was used. One of the clearest illustrations of the relevance of baseline risk is with regard to determining whether a defendant has been negligent. The quality of the defendant's act upon which liability is predicated is its "negligence" or "carelessness," but such acts are also often characterized as having created an "unreasonable risk of harm" to the plaintiff.¹²⁰ If the negligent act of the defendant is conceptualized as having created an *incremental*, "unreasonable" risk to the plaintiff, then the risk to which the defendant has added is the baseline risk inherent in the situation.

Indeed, baseline risk is the inherent risk to the plaintiff exclusive of the incremental risk created by the defendant's negligent acts. Baseline risk is the floor or threshold risk, above which a defendant must have created an incremental risk in order to be found negligent. Thus, the relevance of baseline risk to negligence

¹²⁰ See, e.g., *Cowart v. United States*, 617 F.2d 112, 115 (5th Cir. 1980) (holding as a necessary element for negligence cause of action in Florida "a duty requiring the actor to conform to a certain standard of conduct for protection of others against unreasonable risk"); *Richard P. v. Vista Del Mar Child Care Serv.*, 165 Cal. Rptr. 370, 373 (Ct. App. 1980) (holding that "real basis of negligence is not carelessness, but behavior which society . . . views as involving unreasonable risk of harm to others"); *RESTATEMENT (SECOND) OF TORTS* §§ 281, 282 (1965).

should be clear: the concept of negligence entails the concept of baseline risk, and the establishment of actual negligence in a given case presupposes the ability to distinguish the incremental risk created by the defendant from the actual baseline risk.¹²¹

The "unreasonable" character of the incremental risk (the distinguishing characteristic of "negligent" acts) may also be determined in part by reference to baseline risk. When baseline risk is low, even a relatively small increase in risk might be considered negligent; but when baseline risk is already high, and the defendant adds to it in only a *de minimis* way, negligence is less likely to be found.¹²² This is not the place to explicate an adequate concept of *negligence*. That task requires an independent analysis of the appropriate basis for liability. What is appropriate here, and in the discussions of other tort concepts immediately below, is to indicate the varied tasks for which courts or juries might turn to the concept of baseline risk.

Related directly to determinations of negligence is the judicial doctrine of *res ipsa loquitur*. In certain situations in which the plaintiff is simply unable to establish through direct evidence any specific negligent act of the defendant, the court will allow the jury to infer that in such a situation the plaintiff's injury was

¹²¹ This is clearest in those difficult cases that involve significant baseline risk, such as the "lost chance" cases, *see supra* note 13, in which the plaintiff's ability to demonstrate negligence at all is in part a function of the plaintiff's ability to identify and separate the baseline risk inherent in the situation.

¹²² Baseline risk is probably employed by the finder of fact in several ways in determining whether a defendant engaged in a negligent act. For example, in the collision case involving the defendant crossing into the plaintiff's lane, the defendant's evidence might show that a child ran suddenly into her lane, creating an emergency situation to which the defendant reacted by swerving into plaintiff's lane. In coming to a conclusion about what the "reasonable person would have done under similar circumstances," the trier of fact probably takes into account, in some fashion, the fact that the emergency situation itself increased the inherent, situational risk to the plaintiff, when compared to the risk to the plaintiff in the absence of the emergency. A two lane road with cars approaching from opposite directions is suddenly made riskier for all drivers, with respect to the risk of collision and impact injuries, when a child races suddenly into the roadway. Human reactions to children, delayed reaction times, and the panicky reactions of the split second all contribute to creating a riskier-than-normal situation. The baseline risk of collision injury in an emergency situation is higher than if no emergency existed. In such a case, the emergency situation itself, considered without regard to any particular act of the defendant, involved a higher risk for the plaintiff. The defendant should not be held liable for that increase in the baseline risk. The defendant should merely be liable for any additional risk (over the baseline risk) caused by defendant's negligence. The issue is whether this defendant, under the circumstances, made an already riskier-than-normal situation even riskier than a reasonably prudent driver would have.

unlikely to occur in the absence of *some* unspecified negligent act by the defendant.¹²³ In such cases, the *baseline risk* may be so *low*, relative to the injury incidence that is expected when negligence occurs, that the low baseline risk becomes relevant in helping to conclude that the plaintiff's injury probably happened because the defendant had been negligent.¹²⁴ In such cases, the judicial rule against allowing juries to "speculate" about factual issues is thought to be met in part because of the relatively low baseline risk.¹²⁵

¹²³ See RESTATEMENT (SECOND) OF TORTS § 328D (1965); see also *Spidle v. Steward*, 402 N.E.2d 216 (Ill. 1980). Contrast with such cases a situation in which the baseline risk is low, but the injury may have resulted from the "normal risks of the surgery," and "the injury was of a kind that could occur despite the exercise of reasonable care"—that is, the injury could as easily have occurred as a result of the baseline risk. See *Forsmark v. State*, 349 N.W.2d 763, 769 (Iowa 1984); *Contreras v. St. Luke's Hospital*, 144 Cal. Rptr. 647, 657 (Ct. App. 1978) (holding *res ipsa loquitur* instruction not warranted where sole expert evidence was that resulting injury was rare). In the latter type of case, although *res ipsa* does not apply, the plaintiff might still be able to show that the defendant's specific conduct created an unreasonable incremental risk over the baseline risk, resulting in the plaintiff's specific injury.

¹²⁴ See, e.g., *Spidle*, 402 N.E.2d at 218-20 (holding that if expert witness had answered "no" when asked whether the injurious result would ordinarily result in the absence of negligence, plaintiffs would have introduced sufficient evidence for the first prerequisite of *res ipsa loquitur*). The objective here is simply to show that baseline risk is *relevant* to traditional *res ipsa loquitur* determinations, not to explicate at this time a reconceptualized set of criteria for *res ipsa* that properly uses the concept. Such a reconceptualization, however, would be appropriate and useful.

¹²⁵ Baseline risk also enters into many determinations that a private nuisance exists. In order to establish a private nuisance, it must be shown that there is an "unreasonable" interference with the use and enjoyment of land. See RESTATEMENT (SECOND) OF TORTS § 822 & cmt. k (1979); KEETON ET AL., *supra* note 4, § 87, at 623, § 88, at 629-30. Involved in the determination of what interference is unreasonable, however, is often the concept of baseline risk. Cases sometimes involve determining whether the defendant added any risk to the baseline risk of the relevant kind of injury. See, e.g., *Doe v. Manheimer*, 563 A.2d 699 (Conn. 1989) (involving question of whether crime risk in high crime area was increased by allowing an overgrowth of bushes); *Travis v. Moore*, 377 So. 2d 609 (Miss. 1979) (addressing risk of depression resulting from funeral parlor entering residential neighborhood); *People Express Airlines, Inc. v. Consolidated Rail Corp.*, 495 A.2d 107 (N.J. 1985) (inquiring whether business interruption risk was increased by nearby railway car containing ethylene oxide).

Indeed, the controversy over "moving to the nuisance" may be interpreted as principally about whether the defendant's activities should be included in the baseline risk in a given situation. See, e.g., *Desario v. Industrial Excess Landfill, Inc.*, CA-8346, 1991 Ohio App. LEXIS 3256 (Ct. App. June 24, 1991) (affirming order to certify class action in suit presenting issue whether plaintiff who "moved to the nuisance," a landfill, assumed risk of damage to his property); see also *Boomer v. Atlantic Cement Co.*, 257 N.E.2d 870, 875 (N.Y. 1970) (holding that because permanent damages were awarded to plaintiffs, subsequent purchasers of plaintiffs' land would purchase with defendant's air pollution as part of risk of living at that location).

2. *Contributory Negligence, Assumption of Risk, and Comparative Fault*

The issue of the defendant's negligence must be contrasted with the traditional defenses of contributory negligence and assumption of risk. Unlike the defendant's negligence, which creates risk incremental to the baseline risk in the situation, the plaintiff's negligence is part of the baseline situation. At least in cases where some carelessness on the part of the plaintiff led to the plaintiff's being in the situation in which the plaintiff was injured, the risk to the plaintiff created by her own actions is part of the baseline risk.¹²⁶ Attempts to establish the plaintiff's contributory negligence are really attempts by the defendant to establish that a significant baseline risk existed.¹²⁷ By instituting the affirmative defenses, the courts have elevated this plaintiff-created portion of baseline risk (when it exists) to special legal significance.

Although claims by the defendant of contributory negligence and assumption of risk both lead to determinations of (at least a portion of) the baseline risk, the two defenses are conceptually quite distinct. When a plaintiff is negligent (under a doctrine of

¹²⁶ See, e.g., *Davis v. United States*, 716 F.2d 418, 430 (7th Cir. 1983) (holding that when plaintiff was injured while diving into lake in National Wildlife Refuge, plaintiff's conduct was not merely minimally negligent but willful and wanton, and stating that plaintiff "could have prevented the accident by just not diving"); *Abernathy v. Superior Hardwoods, Inc.*, 704 F.2d 963, 968 (7th Cir. 1983) (holding that, in truck driver's negligence action against unloader for injuries sustained when log tumbled off truck while being unloaded, jury should decide question of truck driver's contributory negligence in not ensuring proper loading of logs and in not getting out of harm's way when he should have heard noise of unloading).

¹²⁷ Such cases are conceptually related to cases in which the plaintiff aggravates her injuries after the tort is committed, or at least fails to mitigate the damages. See, e.g., *Southport Transit Co. v. Avondale Marine Ways Inc.*, 234 F.2d 947, 951-52 (5th Cir. 1956) (holding that doctrine of avoidable consequences, under which plaintiff is denied recovery for those losses resulting from his failure to use reasonable efforts to avoid them, comes into play when defendant has committed an actionable wrong and limits recovery by disallowing only damages plaintiff could reasonably have averted); *Kirby v. Larson*, 256 N.W.2d 400, 416 (Mich. 1977) ("If plaintiff fails to use due care to prevent or reduce damages subsequent to the injury complained of, he or she may not recover the enhanced damages.").

The point here is not the familiar one that under a comparative fault scheme plaintiff's fault in bringing about the accident and plaintiff's fault in failing to mitigate the consequences of the accident become similar in function, insofar as each works to reduce the percentage of the total damages for which the defendant is liable. Rather, the point is that these two forms of defense predicated on the plaintiff's negligence are similar in that each represents an effort by the defendant to identify (and thus escape liability for) plaintiff-created portions of the total baseline risk.

either contributory negligence or comparative negligence), the plaintiff is partially responsible, in a careless way, for the baseline risk that existed in the situation.¹²⁸ Because the defendant should not be held liable for any injuries resulting from baseline risks, it is reasonable, *a fortiori*, that the defendant should not compensate the plaintiff for injuries traceable to the plaintiff's own negligence. Thus, the doctrine of contributory or comparative negligence¹²⁹ may be viewed simply as a corollary of the general principle of non-compensation for injuries attributable to baseline risks.

Assumption of risk, however, presupposes a distinct state of knowledge on the plaintiff's part—one that involves identifying baseline risk as such. At issue in assumption of risk is whether the plaintiff actually appreciated the *difference* between the baseline risk in the particular situation (including any risk that might be created by the plaintiff's own negligence), and the possible incremental increase in risk due to the defendant's negligence.¹³⁰ The

¹²⁸ Of course, there is nothing to prevent defining baseline risk to exclude the portion of risk attributable to the plaintiff. This would conceptualize the total risk as having three possible components: that due to the defendant, that due to the plaintiff, and the residual or remaining risk. For tort cases, however, a tripartite conception would be unnecessarily complicated because the plaintiff's negligence is not always at issue. Moreover, as discussed in the text, there is no real reason to distinguish between the portions of baseline risk due and not due to the plaintiff's negligence, because the plaintiff generally must bear the total costs of injuries or risks not attributable to the defendant.

¹²⁹ There is a judicial and scholarly discussion over what is "compared" in a comparative negligence judgment. Cf. *Cement Div., Nat'l Gypsum Co. v. City of Milwaukee*, 915 F.2d 1154, 1159 (7th Cir. 1990) (holding that doctrine of comparative negligence should be used to assess liability in proportion to the cost to each party of avoiding the entire accident), *cert. denied*, ____ U.S. ____, 111 S. Ct. 1583 (1991); *Burden v. Evansville Materials, Inc.*, 636 F. Supp. 1022, 1036 (W.D. Ky. 1986) (setting forth list of factors considered by court in allocating comparative fault), *aff'd*, 840 F.2d 343 (6th Cir. 1988). Compare *Wooderson v. Ortho Pharmaceutical Corp.*, 681 P.2d 1038, 1058 (comparing fault of parties), *cert. denied*, 469 U.S. 965 (1984) with *Duncan v. Cessna Aircraft Co.*, 665 S.W.2d 414, 427 (Tex. 1984) (comparing causation). See generally Don B. Dobbs, *Accountability and Comparative Fault*, 47 LA. L. REV. 939 (1987); Aaron D. Twerski, *Market Share—A Tale of Two Centuries*, 55 BROOK. L. REV. 869 (1989). This discussion might benefit from the introduction of the concept of baseline risk because a certain amount of metaphysical hair-splitting might be avoided by adoption of the view that what should be compared is contribution to total relevant risk (defendant's contribution versus baseline risk).

¹³⁰ A variation on the requirement of actual knowledge of risk is the requirement sometimes used that the plaintiff *should* have known of the risk in the sense that, if the plaintiff had exercised ordinary or reasonable care, then the plaintiff *would* have been aware of the risk. See, e.g., *Edwards v. Hammond*, 510 So. 2d 234 (Ala. 1987). Even in such cases, however, the risk that is the focus of the analysis is the *incremental* risk created by the defendant's negligence, not the baseline risk inherent in the situation absent the defendant's negligence.

better position would be that the plaintiff "assumes a risk" only if the plaintiff appreciates and consents to accept the *incremental, unreasonable risk* that might be created by the defendant.¹³¹ The risk that the plaintiff is said to appreciate in "assuming the risk" is *not* baseline risk, but rather incremental risk added by the defendant.

In a reconceptualization of negligence theory that explicitly incorporates baseline risk, the above difference between contributory or comparative negligence and assumption of risk might lead to the conclusion that the former could be eliminated as superfluous issues of fact, although the latter should be retained as a legitimate defense.¹³²

3. *Strict Liability for Conduct*

With regard to strict tort liability for injuries proximately caused by an abnormally dangerous activity,¹³³ the concept of baseline risk is relevant to the concept and finding of an "abnormally dangerous activity."¹³⁴ Whether the courts predicate their holdings on "non-natural uses" of land,¹³⁵ the introduction onto the land of something that was not originally there,¹³⁶ or the creation of an unusual

¹³¹ See RESTATEMENT (SECOND) OF TORTS § 496D (1965).

¹³² See Guido Calabresi & Jon T. Hirschoff, *Toward a Test for Strict Liability in Torts*, 81 YALE L.J. 1055 (1972). The concept of baseline risk might also shed light on the relevance of the distinction between "reasonable" and "unreasonable" assumption of risk. Compare *Kirk v. Washington State Univ.*, 746 P.2d 285, 289-91 (Wash. 1987) (holding that jury is entitled to consider reasonable and unreasonable assumption of risk when apportioning damages under comparative negligence scheme) with *Segoviano v. Housing Auth. of Stanislaus County*, 191 Cal. Rptr. 578, 587 (Cal. Ct. App. 1983) (holding that reasonable implied assumption of risk does not reduce plaintiff's recovery). Perhaps both approaches can at least agree on this: damages due to baseline risk (whether "reasonably" or "unreasonably" created or "assumed" by the plaintiff) should not be apportioned to the defendant.

¹³³ See, e.g., *Sterling v. Velsicol Chem. Corp.*, 647 F. Supp. 303, 311-16 (W.D. Tenn. 1986), *aff'd in part*, 855 F.2d 1188 (6th Cir. 1988); *Doundoulakis v. Town of Hempstead*, 368 N.E.2d 24, 27 (N.Y. 1977); RESTATEMENT (SECOND) OF TORTS § 519 (1977).

¹³⁴ For discussions of factors relevant to determining whether an activity is "abnormally dangerous," see RESTATEMENT (SECOND) OF TORTS § 520 (1977); KEETON ET AL., *supra* note 4, § 78, at 554-59.

¹³⁵ See, e.g., *Rylands v. Fletcher*, L.R. 3 H.L. 330 (1868); see also *Peneschi v. National Steel Corp.*, 295 S.E.2d 1, 6 (W. Va. 1982) (discussing hypothetical of having elephants parachute onto farmland for family entertainment).

¹³⁶ See, e.g., *Luthringer v. Moore*, 190 P.2d 1 (Cal. 1948) (hydrocyanic gas for cockroach extermination); *Smith v. Lockheed Propulsion Co.*, 56 Cal. Rptr. 128 (Ct. App. 1967) (rocket motor for test firing); *Rylands*, L.R. 3 H.L. at 330 (dammed water on mill site).

hazard given the surroundings,¹³⁷ baseline risk is usually a relevant consideration. The Restatement (Second) of Torts § 520 suggests a risk/utility balancing for determining whether an activity is “abnormally dangerous,” and this balancing is clearly to take place through a consideration of “common usage” in the area and the inappropriateness of the activity to the place where it occurred.¹³⁸

The Restatement lists six factors to be considered by the court in deciding whether an activity is abnormally dangerous.¹³⁹ Most of these factors in fact relate to the degree to which the incremental risk due to the activity is substantially higher than the baseline risk absent the activity. If the relevant baseline risk for the area of the activity is already high, then marginally increasing that risk by engaging in some additional activity might not be subject to strict liability. If the relevant baseline risk is low, however, courts are more likely to hold an activity abnormally dangerous.¹⁴⁰

4. *Strict Liability for Products*

Whether a product is “defective” in a legally significant sense is a necessary element of strict liability for products.¹⁴¹ Despite the controversy over whether “defectiveness” should or should not be

¹³⁷ See, e.g., *Cities Serv. Co. v. State*, 312 So. 2d 799 (Fla. Ct. App. 1975) (phosphate slimes in creek resulting from phosphate rock mining operation); *State Dep’t. of Env’tl. Protection v. Ventron Corp.*, 468 A.2d 150 (N.J. 1983) (mercury pollution in tidal estuary resulting from defendant’s mercury processing operation). A traditional area of application has been dynamite or “blasting” cases. See, e.g., *Yukon Equip., Inc. v. Fireman’s Fund Ins. Co.*, 585 P.2d 1206 (Alaska 1978); *Alonso v. Hills*, 214 P.2d 50 (Cal. Ct. App. 1950).

¹³⁸ See RESTATEMENT (SECOND) OF TORTS § 520 (1977).

¹³⁹ For example, the Restatement lists as factors:

- (a) existence of a high degree of risk of some harm to the person, land or chattels of others;
- (b) likelihood that the harm that results from it will be great;
- ...
- (d) extent to which the activity is not a matter of common usage;
- (e) inappropriateness of the activity to the place where it is carried on.

Id.; see, e.g., *Langan v. Valicopters, Inc.*, 567 P.2d 218, 220-23 (Wash. 1977) (discussing circumstances important to determination of ultrahazardous nature of activity).

¹⁴⁰ See, e.g., *T & E Indus., Inc. v. Safety Light Corp.*, 587 A.2d 1249, 1261 (N.J. 1991) (holding processing and disposal of radium abnormally dangerous and particularly inappropriate in urban setting); *Klein v. Pyrodyne Corp.*, 810 P.2d 917, 921 (Wash. 1991) (holding fireworks display near large crowds abnormally dangerous).

¹⁴¹ See, e.g., RESTATEMENT (SECOND) OF TORTS § 402A (1965) (formulating strict products liability for “[o]ne who sells any product in a defective condition unreasonably dangerous to the user or consumer or to his property”).

defined in terms of "unreasonable risk,"¹⁴² most would agree that a product is "defective" only if use of it creates an incremental risk over the baseline risk that would exist even if a non-defective product were used. Many courts define the notion of "defect" in terms of the product's being "more dangerous than an ordinary consumer would expect when used in an intended or reasonably foreseeable manner,"¹⁴³ and others define "defect" with reference to risk/benefit balancing.¹⁴⁴ Under either definition, the risk created by the particular product at issue must be incremental to the baseline risk associated with using a non-defective product, in order for the product to be considered defective.¹⁴⁵

¹⁴² Compare *id.* & cmt. g (predicating strict products liability upon product being in a "defective" condition that is "unreasonably dangerous" to consumer) with *Cronin v. J.B.E. Olson Corp.*, 501 P.2d 1153-1163 (Cal. 1972) (requiring plaintiff only to prove that product contained a "defect," not that the defect made the product "unreasonably dangerous"). Both sides in this debate would seem to agree that the risk created by the product defect is incremental to any baseline risk already present in the situation absent any defectiveness (that is, risks from the use of such a product if the defect were absent). Cf. *Phillips v. Kimwood Mach. Co.*, 525 P.2d 1033, 1039 (Or. 1974) (arguing that whether liability is imposed under negligence, ultrahazardness, or strict liability, same process of weighing utility against risk is employed; therefore courts use "the same language and concepts of reasonableness" in determining "unreasonable danger" in products cases).

¹⁴³ See, e.g., *State Farm Fire & Cas. Co. v. Chrysler Corp.*, 523 N.E.2d 489, 494 (Ohio 1988); RESTATEMENT (SECOND) OF TORTS § 402A cmt. g (1965) (defined product as in defective condition if "in a condition not contemplated by the ultimate consumer that will be unreasonably dangerous to him"); *id.* cmt. i (defining product as "unreasonably dangerous" if "dangerous to an extent beyond that which would be contemplated by the ordinary consumer who purchases it, with the ordinary knowledge common to the community as to its characteristics").

¹⁴⁴ See, e.g., *Barker v. Lull Eng'g Co.*, 573 P.2d 443 (Cal. 1978).

¹⁴⁵ A good illustration of the principle that a defendant manufacturer is liable only for creating incremental risks is provided by the doctrine that manufacturers must provide "crashworthy" vehicles. In those cases, the reference situation defining the baseline risk is a *crash* (not caused by the defendant), and the baseline risk is the injury normally associated with such a crash absent a defective product. See *Miller v. Todd*, 551 N.E.2d 1139, 1142 (Ind. 1990) (recognizing the theory of crashworthiness for motorcycles, and quoting with approval *Larsen v. General Motors Corp.*, 391 F.2d 495, 503 (8th Cir. 1968) ("[T]he manufacturer should be liable for that portion of the damage or injury caused by the defective design over and above the damage or injury that probably would have occurred as a result of the impact or collision absent the defective design.")).

In design defect cases, many jurisdictions require that the plaintiff, as part of her *prima facie* case, produce evidence of an alternative, non-defective design that would have avoided the plaintiff's accident. See, e.g., *Troja v. Black & Decker Mfg. Co.*, 488 A.2d 516, 519 (Md. Ct. Spec. App.), *cert. denied*, 494 A.2d 939 (Md. 1985). In such a case, the plaintiff is asking the jury to determine the baseline risk as that associated with using a product with that alternative design. See *supra* note 44.

5. Causation

Whether the cause of action sounds in negligence or strict liability, liability is generally not imposed unless the negligent act, abnormally dangerous activity, or product defect is demonstrated to be a cause of the plaintiff's injury.¹⁴⁶ The two traditional formulations of the cause-in-fact connection required for liability are "but for" causation¹⁴⁷ and "substantial factor" causation.¹⁴⁸ Both formulations presuppose a notion of baseline risk.

First, in requiring that the defendant's negligent act (or the product defect) be shown to be the "but for" cause of the plaintiff's injury, the courts are requiring the plaintiff to demonstrate that her injury did *not* result from the *baseline* situation. In other words, the plaintiff must show that absent the defendant's negligent act, the plaintiff's injury would not have occurred.¹⁴⁹

¹⁴⁶ A significant relaxation of the plaintiff's burden of demonstrating cause-in-fact has occurred in the adoption by some courts of market-share liability. See, e.g., *Sindell v. Abbott Lab.*, 607 P.2d 924 (Cal. 1980), *cert. denied*, 449 U.S. 912 (1980). At least one court has provided a rationale for imposing market-share liability on the basis of the "overall risk produced," or "the amount of risk of injury each defendant created to the public-at-large." *Hymowitz v. Eli Lilly & Co.*, 539 N.E.2d 1069, 1078 (N.Y.), *cert. denied*, 493 U.S. 944 (1989). One court has declined to adopt a "risk-modified market share" approach, at least in the context of DPT vaccine. *Shackil v. Lederle Labs.*, 561 A.2d 511, 513-14 (N.J. 1989) (defining "risk-modified market share" as allocating liability based on "the percentage of the potential risk to the plaintiff caused by each manufacturer of the product").

¹⁴⁷ See *KEETON ET AL.*, *supra* note 4, § 41, at 266; see also *Ratliff v. Duke Power Co.*, 151 S.E.2d 641, 648 (N.C. 1966) (defining "but for" cause of another event as a cause without which the second event would not have taken place).

¹⁴⁸ See, e.g., *RESTATEMENT (SECOND) OF TORTS*, §§ 431-33 (1965); *KEETON ET AL.*, *supra* note 4, § 41, at 266-68; see also *State v. Abbott*, 498 P.2d 712, 726-28 (Alaska 1972) ("[I]f two forces are operating to cause the injury, one due to defendant's negligence and the other not, and each force is sufficient to cause the injury, defendant's negligence may be found to be a substantial factor in bringing about the harm.").

¹⁴⁹ In reaching the conclusion that the defendant's actions were in fact the "but-for" cause of the plaintiff's injury, the trier of fact probably often proceeds on the basis of some inference that the risk of the kind of injury suffered by the plaintiff would have been significantly less under the circumstances, *absent* the negligent behavior by the defendant. See, e.g., *Winstead v. Ed's Live Catfish & Seafood, Inc.*, 554 So. 2d 1237 (La. Ct. App. 1989) (noting that chances of developing septicemia, as plaintiff did from eating raw oysters, depends on number of oysters consumed, virulence of strain of bacteria present, strength of body's immune system, presence of a liver disease, and other underlying risk factors; since plaintiff did not know he had any of the underlying risk factors and had previously eaten raw oysters with no ill effects, failure to warn plaintiff of dangers was not "cause in fact" of plaintiff's harm), *writ denied*, 558 So. 2d 570 (La. 1990). The central importance of such inferences, although perhaps not obvious in garden-variety collision cases, becomes clear in cases involving injuries with normally high background incidence, such as cancer

On the other hand, in requiring that the defendant's negligent act be a "substantial factor" in bringing about the plaintiff's injury, the courts are requiring a showing that the defendant's act played a significant causal role in bringing about the injury—a role in addition to the causal factors already at work in the baseline situation. Thus, a logical and evidentiary relationship exists between baseline risk and what is often called "cause-in-fact."¹⁵⁰

Beyond cause-in-fact, there is also a logical relationship between baseline risk and the notion that the causal chain must also be sufficiently "proximate." Even if a defendant's negligent act is a cause-in-fact of the plaintiff's injury, courts traditionally have required that the causal connection be sufficiently "foreseeable" or "direct," so that imposing legal liability cannot be regarded as unfair or unacceptably open-ended.¹⁵¹ Some potentially troublesome cases that traditionally have been resolved by appealing to the lack of proximity in the causal chain might be resolvable alternatively by reference to baseline risk. For example, an appeal to "unforeseeability" might be in part an assertion that the incremental risk (expected loss) created by the defendant's act was not sufficiently above a reasonable estimate of baseline risk determinable at the time of that act, so that the defendant should be relieved of liability. In other words, foreseeability of harm might be seen as a function of the determinable difference between the expected loss and a reasonable estimate of baseline risk. If the causal connection was so remote and tenuous that the expected loss (risk) would have *appeared* negligible relative to the expected baseline

or infectious diseases. See *In re "Agent Orange" Prod. Liab. Litig.*, 611 F. Supp. 1223, 1260 (E.D.N.Y. 1985) (noting that with time, the number of confounding factors increases), *aff'd*, 818 F.2d 187 (2d Cir. 1987), *cert. denied*, 487 U.S. 1234 (1988); Rosenberg, *supra* note 106, at 857-58 (noting two versions of preponderance rule on causation, probability). In such cases, the trier of fact must determine and take into account the baseline risk in order to decide whether the defendant's actions in fact caused the plaintiff's illness. Cf. *Caiazza v. Volkswagenwerk, A.G.*, 468 F. Supp. 593, 597-99 (E.D.N.Y. 1979) (involving injuries sustained in rear end automobile collision, and issue of allocation as between negligent driving of overtaking motorist, allegedly defective door handle design, and plaintiffs' failure to wear seat belts), *aff'd in part*, 647 F.2d 241 (2d Cir. 1981).

¹⁵⁰ See KEETON ET AL., *supra* note 4, § 41, at 266-68. Just as the concept of baseline risk may prove useful in helping to refine the legal concept of "unreasonable risk," by providing a well-defined threshold of risk to which unreasonable risk is incremental, baseline risk may also prove useful in explicating the concept of "substantial factor." Many of the same factors that render an incremental risk "unreasonable" may also render a causal contribution "substantial." And, perhaps an incremental risk should be substantial in order to be unreasonable.

¹⁵¹ KEETON ET AL., *supra* note 4, § 42, at 272-80.

risk, and would have seemed to merge with it, then perhaps the causal *chain* was not a "proximate" one. In any case, it seems plausible that when courts decide the foreseeability of the harm, they are at least implicitly taking into account the extent to which the likely result of a defendant's actions tended to be indistinguishable, *ex ante*, from the expected baseline risk.

6. *Damages*

As a final illustration of the relevance of the concept of baseline risk in tort litigation, it is worth noting that the notion of baseline risk is routinely used in determining the appropriate amount of damages once a defendant is held liable. Damage awards for unintentional torts are primarily compensatory in nature, having the objective of placing the plaintiff in a position equivalent to the one she was in prior to the tortious injury.¹⁵² Baseline risk is taken into account whenever courts place a ceiling on damage amounts owed by the defendant because to some extent the injury would have occurred anyhow, even absent the defendant's negligence. In *Herskovits v. Group Health Cooperative*,¹⁵³ for example, the court pointed out that damages for a misdiagnosis of cancer "should be awarded to the injured party or his family based only on damages caused directly by premature death, such as lost earnings and additional medical expenses, etc."¹⁵⁴ Whenever compensatory damages are limited by the life expectancy of the plaintiff, taking into account the characteristics and risk factors of that particular plaintiff, then all risks of death other than defendant's negligence are integrated in the life expectancy.¹⁵⁵ Life expectancy, therefore, is an integrated function of all other life-threatening risk factors of the plaintiff, including those present in the reference situation (the baseline risk).

¹⁵² RESTATEMENT (SECOND) OF TORTS § 901 & cmt. a (1979).

¹⁵³ 664 P.2d 474 (Wash. 1983).

¹⁵⁴ *Id.* at 479; see King, *supra* note 13, at 1382 (noting that base value on patient's life should reflect such factors as age, health, and earning potential, taking into account that patient had suffered heart attack).

¹⁵⁵ *Cf.* DOBBS, *supra* note 32, at 571-73 (noting that because mortality tables, which attempt to show average future life at any given age, are based on experience with particular groups of people, such as those that purchase life insurance or annuity policies, courts usually permit testimony showing good or bad health of particular plaintiff or decedent, or other facts that tend to increase or decrease the individual's life expectancy).

7. *Conclusion on Relevance*

In connection with each of the above examples, the law of torts is clearly interested in identifying the incremental risk for which the defendant is responsible, in contrast to the baseline risk. Establishing the existence and magnitude of the baseline risk is therefore relevant in various ways to establishing liability under these traditional tort concepts. In addition, *rethinking* various concepts and liability doctrines by utilizing the concept of baseline risk might lead to useful *reformulations* of the traditional elements of the tort causes of action. For example, if in a comparative fault context the finder of fact were told to allocate percentages of fault based on a comparison of the *incremental unreasonable risk* created by the defendant's negligent act with the *baseline risk* inherent in the situation, then such a formulation would avoid many of the nearly metaphysical puzzles about what is being compared.¹⁵⁶ Such reevaluations would have to take into account the specific problems and policies to which the traditional solutions have been responsive and would have to determine whether proposed reformulations would meet those needs more effectively and efficiently. Such extensive investigations are beyond the scope of this Article. What must suffice here is merely to suggest the usefulness of a well-defined concept of baseline risk in such reevaluations.

B. Meeting Burdens of Production with Sufficient Evidence

It might seem at first that introducing the concept of baseline risk raises no novel issues of burden of production. At least in the absence of any reformulations of the traditional factual elements of a cause of action, it might seem that if baseline risk is relevant to a traditional element (such as negligence, product defect, or contributory fault), then the burden of producing sufficient evidence on baseline risk should fall on that party that traditionally bore that burden for the relevant element. For example, because the plaintiff bears the burden of production on whether the defendant acted negligently, then it might seem that the plaintiff should bear the burden of establishing the baseline risk to the extent that

¹⁵⁶ See, e.g., *Murray v. Fairbanks Morse*, 610 F.2d 149, 158 (3d Cir. 1979) (discussing "the current conceptual confusion among the courts, and the difficulties confronting us in comparing plaintiff's personal conduct with the strict liability of the defendant for his product defect"); *supra* note 129.

doing so is necessary in order to establish that the defendant has created an unreasonable risk of harm.

Although this general principle provides a reasonable starting place, it should be recognized that three somewhat new issues *do* arise once baseline risk is taken seriously. First, because baseline risk has seldom received explicit attention, there is some question of how much and what kind of evidence it is reasonable to expect a party to produce. Second, the explicit recognition of the inherent potential for different kinds of uncertainty in determining baseline risk leads to the question of which party should bear what burden of production on resolving or determining the associated uncertainty. Finally, because baseline risk is the aggregate risk created by many causal agencies (including the plaintiff, persons not party to the litigation, and purely natural causes), it might not always be so clear that the party with the traditional burden of production for a particular element should automatically shoulder a similar burden for baseline risk. While comprehensive discussion of these considerations must await the reevaluation of each traditional element, a few general remarks are possible here under each topic.

1. *Nature of the Evidence*

To a great extent, traditional tort litigation has succeeded in avoiding explicit consideration of baseline risk because juries have been relied on to bring to the litigation their own experience with the reference situation and to draw upon their own experience to intuit a sufficiently accurate estimate of baseline risk. But unless the reference situation is extremely commonplace and the baseline risk intuitable, the experience samples of the jurors are likely to be unrepresentative, because those experiences are necessarily convenience samples—the happenstance and anecdotal experiences of individuals. Moreover, jurors are not in general trained to evaluate the representativeness of those experiences or to reach accurate conclusions about resulting risks. In many lawsuits, there will be no sound evidentiary basis for even deciding *whether* a juror's experience *does* provide a generalizable sample of the reference situation, let alone for evaluating the probable sampling error associated with any juror's conclusion (or any jury's collective conclusion) about baseline risk.

The function of expert witnesses is, of course, to educate the jury concerning matters beyond its experience. When an expert is needed with respect to baseline risk, the kind of expert required is one whose personal experience, specialized training, or research

provides information about the baseline risk associated with the reference situation. To the extent needed in the case, an expert's testimony about baseline risk should include testimony about the kinds of inherent uncertainty discussed in Part II.¹⁵⁷ The expert might be required to present sufficient evidence concerning the conceptual, measurement, modeling, sampling, and causal uncertainty inherent in the expert's estimate of the baseline risk, so that the trier of fact can decide whether such uncertainties are within acceptable limits.¹⁵⁸ In the proper case, failure to produce evidence on important uncertainties might constitute grounds for excluding the testimony or directing a verdict.

2. *Reducing Uncertainty*

The question also arises whether, simply because a party has the burden of production on the issue of baseline risk, that party should also have the burden of producing evidence to reduce *every* kind of associated uncertainty to acceptable levels. As an example, assume that Mr. Stubbs, in his negligence action,¹⁵⁹ has the burden of producing evidence that the baseline risk was sufficiently determinable so that, more likely than not, the defendant created an incremental, unreasonable risk. It would seem to be a sensible policy to require Stubbs to provide evidence, in the form of empirical data, that the baseline risk of typhoid fever encountered simply by being a resident of Rochester does not reasonably account for the number of cases observed in Rochester in 1910. Using today's statistical techniques, Stubbs would need to offer evidence that: (a) the data presented are for the appropriate public health variables (conceptual uncertainty is within reasonable bounds); (b) the data are reasonably valid and reliable (measure-

¹⁵⁷ The question here is not the weight of the testimony or evidence, of course, but only what constitutes minimal sufficiency so that a reasonable jury could make a sufficiently accurate determination of baseline risk.

¹⁵⁸ What precisely those "acceptable limits" are has not been well analyzed within the law—other than to hold that the overall conclusions as to the factual predicates for liability must be established as "more likely than not." The proper interpretation of this phrase and the question whether *each* factual issue must be independently established as "more likely than not" are matters of some controversy. See L. JONATHAN COHEN, *THE PROBABLE AND THE PROVABLE* 58-67 (1977); L. Jonathan Cohen, *The Logic of Proof*, 1980 CRIM. L. REV. 91, 95-97; Sir Richard Eggleston, *The Probability Debate*, 1980 CRIM. L. REV. 678, 682-85; Glanville Williams, *The Mathematics of Proof*, 1979 CRIM. L. REV. 340, 340-42.

This problem of what kind and extent of uncertainty to accept in tort law is not peculiar to baseline risk, however, and must be left for another day.

¹⁵⁹ See *supra* text accompanying notes 66-69, 104-105.

ment uncertainty); and, (c) the relative risk or odds ratio associated with the incidence of typhoid fever in Stubbs's situation is statistically significantly elevated over what one would expect in that situation, even allowing for chance variation from year to year (modeling and sampling uncertainty).

Having produced evidence that meets these enumerated concerns, perhaps the plaintiff, in at least some circumstances, should be allowed to take her case to a jury. Noticeably absent might be evidence on the etiology (possible routes of causation) of typhoid fever due to causes other than the defendant's negligence. But what if in fact little or nothing were known about that etiology? Would it be sound public policy to hold the plaintiff's case hostage to that kind of scientific advance, even when descriptive evidence of increased risk is available?

If the defendant wished to rebut the claim that Stubbs's case of typhoid fever was more likely due to drinking the defendant's contaminated water than to other causal factors normally encountered by residents of Rochester, he could attack Stubbs's data (as being inappropriate, invalid, or unreliable) or Stubbs's sampling or modeling, or he could go further by trying to identify some particular causal agent other than the contaminated water that was as likely to be at work in Stubbs's case. In effect, this is the conclusion reached by the court of appeals in *Stubbs*, which held that the plaintiff did not have to rule out every possible cause as not being operative in his case.¹⁶⁰

Beyond relying on the defendant's natural interest in rebutting a *prima facie* case, a court might place an affirmative burden of production on the defendant concerning causal factors other than the defendant's negligence, once the plaintiff has provided sufficient evidence that the risk to him created by the defendant was statistically significantly increased over the baseline risk. Such a burden of production would help ensure that whatever scientific information on causation is available would be placed before the jury, so that causal uncertainty could be evaluated. Moreover, to the extent that uncertainty reduction is the objective, it might make sense to require the party with the greatest or cheapest access to risk information to produce evidence on causal uncertainty.

Resolution of these issues depends on policy concerns about who should bear the cost of generating what information and who

¹⁶⁰ See *Stubbs v. City of Rochester*, 124 N.E. 137, 140 (N.Y. 1919).

should bear the loss if little is known about baseline risk. Once the kinds of inherent uncertainties are understood, those policy concerns may lead to a different allocation of burdens of production for different kinds of uncertainty. At a minimum, what can be drawn from the above discussion is that the various kinds of scientific uncertainty associated with determinations of baseline risk need not be dealt with uniformly, when the issue is which party should bear the burden of production.

3. *Traditional Allocations*

The above discussion should also caution against applying the general principle that the party traditionally bearing the burden of production with respect to a factual element should also automatically bear the burden of production with respect to baseline risk, when establishing such risk is relevant to establishing that factual element. In the illustration above, although the plaintiff traditionally bears the burden of production on negligence and proximate cause, there might be reasons to regard a primarily statistical showing by the plaintiff as sufficient for a *prima facie* case, and even for thereafter imposing a burden of production on the defendant with regard to alternative means of causation. If taking baseline risk and its associated uncertainties seriously leads to reformulating altogether at least some aspects of traditional tort causes of actions, more precise questions about burdens of production and sufficiency of evidence will be asked, and more useful and informative answers may be forthcoming.

C. *Allocating the Burden of Persuasion*

The possibility that taking baseline risk seriously will lead to reformulating at least some traditional concepts and doctrines leads to consideration of the possibility that such reformulations may also lead to reallocations of the burden of persuasion. The discussion just above provides a suggestion on point. If in certain kinds of cases, like *Stubbs*, a plaintiff's *prima facie* case were to be met by an essentially statistical showing, then the question arises what the jury should be told about what each party has to prove. Should jury instructions remain couched in the traditional concepts, because of their supposedly intuitive appeal, or should the trier of fact be instructed with more precise, but perhaps more difficult, concepts? Is the concept of baseline risk, whatever its merits in helping the court to decide motions on evidentiary relevance and

sufficiency of evidence, necessarily helpful in having a jury arrive at a legally correct determination? And if the concept of baseline risk were utilized in jury instructions, who would have the burden of persuasion on what the baseline risk is? Traditionally, the vague notion of "normal risk" has been imparted to the jury in nearly subliminal ways, by leaving it implicit in such phrases as "ordinary care," "under similar circumstances," and "proximate cause." Essential to the task of reevaluating the traditional elements of liability is deciding whether traditional instructions are practically useful, or whether they are more likely to produce jury determinations of factual issues that are unacceptably wide of the mark.¹⁶¹

Taking baseline risk seriously may also introduce more precise questions about how best to allocate the burden of persuasion and the risk of not dispelling uncertainty about baseline risk. Perhaps one consideration should be which party is the "best uncertainty optimizer": the party in the best position to decide whether it is economically sensible to incur the costs of generating and assembling the information needed to reduce uncertainty further.¹⁶² One goal is to minimize the administrative and transactional costs of litigation, through optimizing the level of uncertainty reduction given the stakes in the litigation. When the plaintiff has unique access to information about the true costs of the injury and the circumstances of the accident, and has discovery tools available with which to learn about causation, placing the burden on the plaintiff makes good sense. But perhaps the risk of non-persuasion should be placed on the defendant in certain cases where the plaintiff is not the "cheapest uncertainty reducer," or "best uncertainty optimizer." Something like this is probably at work in such cases as *Ybarra v. Spangard*,¹⁶³ in which the defendant medical personnel involved in the plaintiff's operation were given the burden of exonerating themselves. In effect, the defendants were given the burden of establishing that some baseline factor in fact caused the plaintiff's injury. Focusing attention on a well-defined concept of baseline risk may lead to more fruitful formulations of the

¹⁶¹ This question may have different answers depending upon whether no expert testimony is needed or presented in the case (the jury is capable of intuitively estimating baseline risk), or whether expert testimony has been presented and the jury would benefit from judicial guidance on how to determine its relevance and probative value. See *supra* note 44.

¹⁶² This suggestion obviously follows the paradigm established in torts analysis by Dean Guido Calabresi. See CALABRESI, *supra* note 63, at 135-61.

¹⁶³ 154 P.2d 687, 691 (Cal. 1944).

precise issues in such cases, and to rationales for fairer and more efficient allocations of the burden of persuasion.

CONCLUSION

A vague notion of "normal risk" is fundamental in tort law. A basic principle of torts is that the defendant should not be liable for injuries that result from the normal risks of life, or from those situational risks to the plaintiff that are not fairly chargeable to the defendant. Because this principle is so fundamental, the notion of normal risk is implicit in many of the concepts used and determinations made by judges and juries in assessing liability, and is involved when addressing such issues as negligence, abnormally dangerous activities, product defectiveness, contributory fault, assumption of risk, and proximate cause. This Article has tried to clarify what is meant by "normal risk" by defining a concept of baseline risk that is designed to be useful in tort litigation.

In designing this concept, and in refining the understanding of its use by exploring the kinds of uncertainties necessarily associated with determinations of baseline risk in individual cases, this Article has also laid a conceptual foundation for redefining, or at least refining, other central concepts of tort liability law. In such redefinitions, there is the opportunity to make tort theory more responsive to the growing need for a unified theory of accident law. Such a unified theory should bring together retrospective tort adjudication and prospective administrative rulemaking, by formulating a single substantive and procedural framework that is useful in achieving both compensatory and regulatory goals, and in facilitating interactive fact-finding and policy making. Such a unified theory should also create a bridge between the concepts of the law and the concepts of the sciences, so that the latter can be used by decision makers to make legal decisions that are more efficient and more effective. A cornerstone in such a unified theory of accident law is a well-defined and well understood concept of baseline risk.