TOXIC TORTS AND CAUSATION: TOWARDS AN EQUITABLE SOLUTION IN AUSTRALIAN LAW

PART I: LEGAL REASONING WITH UNCERTAINTY†

PAOLO F RICCI* AND NATALIE J GRAY**

I. SCIENTIFIC EVIDENCE AND CAUSATION

In toxic tort law, past and future injuries are in issue; in regulatory law, prospective injuries to broader classes are of concern.[1] In both, scientific evidence on causation through exposure and response models consists of clinical studies, animal bioassays, epidemiological studies, and tests on lower organisms. Establishing causation on these heterogeneous data requires reasoning with uncertain evidence using statistical and mathematical models.[2]

Scientific and legal causation merge in an uncertain network of feedbacks, variable inputs and outputs surrounded by different degrees of knowledge. It is doubtful that a trier of fact could adequately decide between difficult and conflicting evidence on the basis of 'common sense' and their 'ordinary experience'. However, otherwise meritorious claims should not fail because the

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* University of California, Berkeley, USA; PhD, LLM, MPA, MA, MSc Ricci & Molton, 685 Hilldale Ave, Berkeley, CA 94708, USA; Professor, University of San Francisco, USA; Scholar, UC Berkeley, USA; Visiting Chair, Faculty of Law, University of Wollongong, Australia.

** BSc, LLB (Hons) (Woll).

1 See *US v Vertac Chemical Corp*, 489 F Supp 870 (E D Ark, 1980), under RECRA, 42 USC § 6973 et seq; CWA, 33 USC §§ 302(a), 309 (b), 402, and 504. The court held that "endangerment" occurs where the potential for harm exists, not that the harm has occurred, and that term is probabilistic.

2 Increased relative risk has been the linchpin of the plaintiffs' cases in DES, Dalkon Shield, swine flu vaccine, smoking and radioactive fallout. Biological and medical evidence can conflict with epidemiologic studies resulting in judicial rejection of the former in favour of the latter.

causal chain is not within ordinary experience.[3] There is a need to coherently, consistently, and formally account for uncertainty and variability before legal decisions are made. It is time for a change in the treatment of probabilistic scientific evidence and causation in toxic tort cases in Australia. This paper lays the foundations for such change.

Part I develops the current legal status of causation and the admissibility of scientific evidence in Australian law. We conclude that probabilistic reasoning is consistent with the jurisprudence of cause in fact and proximate cause. Part II examines the ways to do so and uses health related risk assessment to illustrate the limits to scientific knowledge and uncertainties in scientific reasoning.

A. Admissibility of Scientific Evidence[4]

Despite a number of miscarriages of justice from the admission of unreliable scientific evidence,[5] Australian courts have not yet established firm principles guiding the admissibility of expert opinions and other scientific evidence. However, a number of principles[6] derive from Chief Justice Dixon's statement in *Clark v Ryan*[7] that expert opinion is admissible "whenever the subject matter of inquiry ... so far partakes of the nature of a science as to require a course of previous habit, or study, in order to obtain a knowledge of it". In toxic torts, a requirement is that the evidence must derive from a 'field of expertise'. Although no Australian court has definitively asserted what is meant by a 'field of expertise', it often seems to have been equated with the 'general acceptance' test of *Frye v United States*,[8] foreshadowed in *R v Parker*.[9]

The cases that adopted the *Frye* test are impressive. In *Lewis v The Queen*,[10] the court held, following *Carroll v The Queen*,[11] that odontological evidence identifying a suspect from a bruise on the victim's leg, was inadmissible as not generally accepted forensic dentistry for identification. Following Muirhead AJ "[t]he science of forensic odontology is developing ... [T]here is ... a body of

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3 The injustice of requiring a deterministic description of the disease process which science has not yet been able to deliver is discussed by TA Brennan and RA Carter, "Legal and Scientific Probability of Causation of Cancer and other Environmental Diseases in Individuals" (1985) 10 *Journal of Health, Politics, Policy and Law* 33.

4 Several cases discussed in this section have also been cited by SJ Odgers and JT Richardson "Keeping Bad Science out of the Courtroom - Changes in American and Australian Expert Evidence Law" (1995) 18 *UNSWLJ* 108. *Daubert* is criticised by G Edmond & D Mercer, "Keeping 'Junk' History, Philosophy and Sociology of Science out of the Courtroom: Problems with the Reception of *Daubert v Merrell Dow Pharmaceuticals Inc*" (1997) 20 *UNSWLJ* 48.

5 See, for example, the *Royal Commission Report concerning the conviction of Edward Charles Splatt*, 1984 (the *Shannon Report*); the *Royal Commission of Inquiry into Chamberlain Convictions*, 1987 (the *Morling Report*); and *Report of the Inquiry Pursuant to s 475 of the Crimes Act 1900 into the Guilt of Douglas Harry Rendell of the Murder of Yvonne Kendal*, 1989 (the *Hunt Report*). For more details see J Bourke, "Misapplied Science: Unreliability in Scientific Test Evidence" (1993) 10 *Australian Bar Review* 123.

6 These principles have been applied inconsistently.

7 (1960) 103 CLR 486 at 491.

8 293 F 1013 (1923).

9 [1912] VLR 152 at 154.

10 (1987) 88 FLR 104.

11 (1985) 19 A Crim R 410.

opinion that casts some doubt on the processes of positive identification by these means".[12] Maurice J concurred, stating that although it "could not be asserted that the *Frye* test has become law in Australia; nonetheless, it provides a useful guideline in determining whether novel forensic evidence should go before a jury".[13]

King CJ reasoned similarly in *R v Runjanjic and Kontinnen*,[14] concerning the admissibility of evidence of the "battered woman syndrome". He held that the evidence should have been put to the jury, because "[a]n essential prerequisite to the admission of expert evidence on that syndrome is that it be accepted by experts competent in the field of psychology or psychiatry as a scientifically established aspect of ...".[15] He repeated this view in *R v C*,[16] that, before a topic can be introduced for expert evidence, it must be "proved that there is a scientifically accepted body of knowledge", referring to the behaviour of victims of sexual abuse. Other cases that have followed *Frye* when considering if the evidence falls within a 'field of expertise' include *R v Jarret*,[17] *R v Lucas*,[18] *R v Jamieson*[19] and *Eagles v Orth*.[20]

Although the *Frye* test might reduce convictions from questionable scientific ('junk science') evidence,[21] it can be unjust for both the victims of toxic torts and the defendants. Not being mainstream science is not synonymous with 'junk science'.

B. Asymmetry of Information

The asymmetric treatment of scientific information occurs in cases involving scientific and probabilistic evidence of increased risk of future harm, enhanced susceptibility of disease, cellular or DNA damage as present injury, and wherever new scientific evidence is reputable, but not mainstream. Rapid scientific advances clash with *Frye*. It would not allow those advances to be admitted until they became "generally accepted" in the scientific community. By then, a number of meritorious actions may have failed.

Thus, Australian courts would do well to follow the approach of Street CJ in *R v Gilmore*[22] who, considering that spectrographic voice analysis was a 'recognised field', held:[23]

> Absolute certainty ... or unanimity of scientific opinion is not required for admissibility. 'Every useful new development must have its first day in court' ... Unless an exaggerated popular opinion ... makes its use prejudicial or likely to

12 Note 10 *supra* at 116.
13 *Ibid* at 122.
14 (1991) 56 SASR 114.
15 *Ibid* at 119.
16 (1993) 60 SASR 467 at 473.
17 (1994) 73 A Crim R 160 at 165.
18 [1992] 2 VR 109 at 115: evidence must be based "in a body of recognised scientific theory".
19 (1992) 60 A Crim R 68 at 77: scientific opinion must be in a "recognised field of scientific expertise".
20 (1976) Qd R 313 at 320 provides that what was required is a "recognised field of scientific knowledge".
21 This seems to have been a major concern of the courts.
22 [1977] 2 NSWLR 935 at 938-9.
23 *Ibid*, quoting *United States v Baller* (1975) 519 Fed 2d 463 at 466-7.

> mislead the jury, it is better to admit relevant scientific evidence ... and allow its weight to be attacked by cross-examination and refutation ... .

Expert opinion assists the trier of fact, given all of the relevant evidence.[24] A formal and coherent balancing of the advantages and disadvantages of admission to both parties must be undertaken. Indeed, in *R v C*[25] King J, deciding the case on the evidence failing the 'general acceptance' test, emphasised the importance of determining whether the evidence is unnecessary and would merely overwhelm the triers of fact, or whether without that introduction they would be 'misled'. The evidence was not thought to add to the jury's common sense view and was excluded. King CJ reached a different conclusion in *R v Runjanjic*[26] after examining the recent literature on "battered woman syndrome". He found that the reactions of battered women were counterintuitive and that the jury would be misled without expert opinion.

In criminal trials the accused must be protected against the often-superior scientific evidence mustered by prosecutors. It is not surprising that Maurice J in *Lewis v The Queen*,[27] after examining the 'general acceptance' tests, proposed tightening the standard for admissibility where the Crown seeks to introduce novel scientific evidence.[28] He suggested that before admitting such evidence, the Crown should demonstrate its reliability.

His Honour might see a reliability test as being more stringent than a 'general acceptance' test. However, if used as part of a balancing test assisting the trier of fact, justice demands a flexible standard. Street CJ stated that in *R v Gilmore*:[29] "[T]o recognise ... a degree of risk of inaccuracy and to recognise a degree of caution in the use of the evidence, is far from treating the evidence as inadmissible". It thus seems that reliability is a factor, not to exclude evidence, but to better inform the fact finder of the weight it should be given. This balancing was supported in a number of other cases including *Casley-Smith v F S Evans & Sons Pty Ltd and District Council of Stirling (No. 1)*,[30] *R v Tran*,[31] and *Murphy v R.*[32]

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24 See *R v Jarrett*, note 17 *supra* about probative expert evidence.

25 Note 16 *supra* at 474.

26 Note 14 *supra* at 120-21.

27 Note 10 *supra* at 124.

28 Presumably to avoid a repeat of Australia's infamous miscarriages of justice. See note 5 *supra*.

29 Note 22 *supra* at 941.

30 (1988) 49 SASR 314 at 320 where Olssen J commented that, in considering admission of evidence, one factor is "whether it forms part of a body of knowledge or experience ... sufficiently organised or recognised to be accepted as a reliable body of knowledge or experience, ... which ... would render his opinion of assistance to the court".

31 (1990) 50 A Crim R 233 at 242-3.

32 (1989) 167 CLR 94 at 130-1, per Dawson J. His Honour emphasises that expert opinion must be of value to the trier of fact as the unnecessary admission of expert evidence may divert the jury from making a decision in accordance with common sense, unduly prolong the trial, and shift focus to a dispute between competing theories.

The US Supreme Court, in *Daubert v Merrell Dow Pharmaceuticals*[33] developed a test of the extent to which the evidence can assist the trier of fact. The factors include: reliability (the empirical testing of scientific hypotheses that are falsifiable), scientific validity of the methods and reasoning and scientific peer review. It is unclear whether the High Court of Australia will adopt *Daubert*.

II. RELIABLE SCIENTIFIC EVIDENCE

Odgers and Richardson[34] argue that, given the lack of guidance in the new Australian uniform evidence legislation, the similarity of s 79 of the *Evidence Act* 1995 (Cth)[35] to Rule 702 of the US Federal Rules of Evidence[36] (the subject of *Daubert*) and the developing trend of some Australian courts to require reliability and helpfulness as a criteria of admission, the result in Australia is *Daubert* type analysis. Rule 702 explicitly includes the requirement that the evidence "will assist the trier of fact", which is absent from s 79. Thus, it is open for the High Court to either adopt a more stringent test, or to ignore previous authority and adopt a test analogous to the English position whereby exclusion would be entirely at the discretion of the judge.[37] The latter option seems unlikely in criminal cases from Australia's past experiences.

The English test, Odgers and Richardson argue,[38] is undesirable because it shifts the onus of proof from the party introducing the evidence to the party attempting to keep it from the trier of fact. In toxic torts, forcing the defendant who has more resources and knowledge than the plaintiff to produce exculpatory scientific evidence *increases* the rigour of scrutiny; provided, naturally, that there is symmetric treatment of that information. Shifting the burden to the defendant can overcome the inequities between parties who have special knowledge or are in the best position to show lack of negligence.[39] The

33 61 USLW 4805 (1993) at 4808-09. The New Jersey Supreme Court in *Rubanick v Witco Chemical Corporation* 593 A 2d 733 (NJ 1991) at 747-8, held that "a scientific theory of causation that has not yet reached general acceptance may be ... sufficiently reliable if ... based on a sound ... scientific methodology ... reasonably relied on by experts".

34 Note 4 *supra*, at 127-9.

35 Section 79 provides: "If a person has specialised knowledge based on a person's training, study or experience, the opinion rule does not apply to evidence of an opinion of that person that is wholly or substantially based on that knowledge". Cf s 76 which provides that opinion evidence is inadmissible.

36 Rule 702 states: "If scientific, technical or other specialised knowledge will assist the trier of fact ... a witness qualified as an expert by knowledge, skill, experience, training or education may testify thereto in the form of an opinion or otherwise".

37 Exclusion of evidence at an Australian judge's discretion would consider that its probative value is outweighed by creating prejudice, misleading or confusing or resulting in waste of time: s 135 *Evidence Act* 1995 (Cth). Once admitted, the trier of fact would evaluate the weight of the evidence. See Editorial, "Expert Evidence" (1994) 1 *Journal of Law and Medicine* 135 at 135.

38 Note 4 *supra* at 128.

39 *Sindell v Abbot Laboratories*, 6 Cal 3d, 163 Cal Reptr 132, 607 P 2d 924, cert den'd, 101 S Ct 286 (1980).

'producer' of the tortious act is more efficient than the affected party in sharing the cost of reducing the risk; tort law facilitates that exchange.

Reliability under *Daubert* means that "[t]he adjective 'scientific' implies a grounding in the methods and procedures of science".[40] Further, "it would be unreasonable to conclude that the subject of scientific testimony must be 'known' to a certainty; arguably, there is no certainty in science".[41]

Given the Australian experience with scientific evidence, its courts should adopt *Daubert* type test. Clearly, it cannot prevent some 'bad' science from reaching the trier of fact. And, we concur with Edmond and Mercer who state that the praise of *Daubert* has been:

> flawed because it has relied on a naive positivist image of science as a form of knowledge defined by its possession of a singular, transhistorical and efficacious scientific method and unique institutional structures.[42]

Nevertheless, *Daubert* is consistent with the formal and coherent view of uncertainty and causation we discuss, unlike *Frye*. Thus, it will help decide such issues, critical in toxic torts, as where the evidence from animal and *in vitro* tests, uncontradicted by epidemiological evidence, is "at the frontier of medical and epidemiological inquiry".[43] *Daubert* helps when legal sufficiency exists without scientific certainty,[44] where expert opinion is unsupported because it is personal belief[45] and where the scientific community has not reached consensus.[46]

Judges: Gatekeepers of Science?

Trial judges either admit or bar scientific evidence. The standard for appellate review is 'abuse of discretion'. The US Supreme Court in *General Electric et al v Joiner et Ux* has redefined it,[47] giving trial judges considerable deference in either excluding or admitting scientific evidence.[48] Joiner was exposed to fluids

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40 Note 33 *supra* at 4808.

41 *Ibid.*

42 Note 4 *supra* at 51.

43 *Ferebee v Chevron Chemical Co*, 736 F 2d 1529 (DC Cir 1984, cert den'd, 469 US 1062 (1984). If the expert admits causation (paraquat poisoning), then the "cause-effect relationship need not be clearly established by animal or epidemiological studies before a doctor can testify that, in his opinion, such relationship exists. As long as the basic methodology ... to reach such a conclusion is sound" (at 1535-6).

44 In *Ferebee*, the court held that what resolves causation "is not scientific certainty but legal sufficiency": *ibid* at 1536. See also *Oxendine v Merrell Dow Pharmaceuticals Inc*, 506 A 2d 1100 (DC Ct App1986), aff'd 563 A 2d 330 (D C Ct App 1989).

45 *Viterbo v Dow Chemical Co*, 826 F 2d 420 (5th Cir 1987), (rejection on Federal Rule of Evidence 703).

46 *Brock v Merrell Dow Pharmaceuticals Inc*, 874 F 2d 306 (5th Cir 1989) (reversing judgment for plaintiff by jury and granting a judgment n.o.v.), modified, 884 F 2d 166, reh. *en banc* denied, 884 F 2d 167 (1988). This case illustrates the misunderstanding of probabilities by the federal judicial panel, believing that confidence intervals correct for systematic bias, that statistical significance is equivalent to an all or none result, not realising that the choice of confidence level is convention: at 168, per Revley J (dissenting).

47 97 Daily Journal DAR 15051, December 16, 1997; 118 S Ct 512 (1997); citing *Daubert v Merrell Dow Pharmaceuticals Inc*, 509 US 579 (1993), per Renquist CJ.

48 *Ibid* at 15053. The "abuse of discretion" standard means that the reviewing court must find that the trial court's ruling was "manifestly erroneous".

containing Polychlorinated Biphenyls (PCBs) at apparently much smaller concentrations than the experimental animals. The cancer he suffered was small-cell carcinoma. Animal experimental results were based on infant mice, peritoneally injected with massive doses of PCBs, resulting in bronchogenic cancer.

The plaintiff's experts used a 'weight of the evidence' heuristic to assess the causal relationship between Joiner's exposure and lung cancer.[49] The evidence was epidemiological data, animal bioassays results and the plaintiff's medical record. After scrutinising *some* of the studies *individually*, the District Court concluded that those did not go past the gate. The court attacked the experts' opinions, rather than their principles and methodology.[50] On review, the Court of Appeal stated:

> Opinions of any kind are derived from individual pieces of evidence, each of which by itself might not be conclusive, but when viewed in their entirety are the building blocks of a perfectly reasonable conclusion, ... reliable enough to be submitted to a jury along with the tests and criticisms cross-examination and contrary evidence ... supply ... .[51]

Because the plaintiff's experts would not testify to a causal association "between increases in lung cancer and PCB exposure among the workers they examined" from their own studies, the Supreme Court agreed with their exclusion.[52] One witness testified that it was "more likely than not that Mr Joiner's lung cancer was causally linked to cigarette smoking and PCB exposure" and another that "lung cancer was caused ... in a significant degree by the material with which he worked".[53] These experts did not rely on epidemiology using, instead, results of the animal (mice) studies. The Court's review of the epidemiology concluded that those studies did not provide a sufficient causal link, either because the positive findings were not statistically significant or because of confounding or lack of positive findings altogether.[54]

When the case was decided at the US Supreme Court, Stevens J separated the *relevance* of the testimony from its *reliability*.[55] Relevance, in his view, is that if some exposure to other chemicals (for example, to furans and to dioxins) does not take place, then only the PCBs are relevant. Testimony on the furans and

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49 The part dissent, part concurrence by Stevens J quotes the expert (*ibid* at 15057, n 4, citation omitted): "(given the plaintiff's question) 'Have I got a risk of getting cancer from this?' That those studies don't answer the question, that I have to put them all together in my mind and look at them in relation to everything I know about the substance and everything I know about the exposure and come to a conclusion. ... [w]hen I say, 'to a reasonable medical probability as a medical toxicologist, this substance was a contributing cause ... that is a valid conclusion based on the totality of the evidence presented to me".

50 *Ibid* at 15056.

51 Opinion, *ibid* at 15057, citing 78 F 3d 524, 532 (CA 11 1996). *Daubert* states that "vigorous cross-examination, presentation of contrary evidence, and careful instructions on the burden of proof are the appropriate means to attack shaky but admissible evidence": note 41 *supra* at 596.

52 *Ibid* at 15052, refusing an expert's *ipse dixit* as sufficient basis for admitting evidence.

53 *Ibid* at 15053.

54 The plaintiff relied on four occupational epidemiological studies, all of which found lung cancers, but PCBs exposure in those was confounded by other toxic agents, the studies did not support a causal association or PCBs were not mentioned in the exposure: *ibid* at 15054.

55 Concurring in part and dissenting in part.

dioxins is *Daubert* 'irrelevant'. Reliability follows *Daubert* where "[t]he focus ... must be solely on principles and methodology, not on the conclusions it generates". Stevens J reminded the Court that the US EPA uses weight of evidence, as we will discuss in Part II, precisely to achieve health protection. Finally, as Stevens J stated, *Daubert* "forbids trial judges from assessing the validity or strength of an expert's scientific conclusion, which is a matter for the jury".[56]

III. BALANCING ADVERSARIAL EVIDENCE

The 'more likely than not' standard is a well established legal principle for decision making in toxic torts:

> [T]he plaintiff must produce evidence to establish, with reasonable certainty, a causal relationship between the injury and the subsequent condition, so that the jury will not be indulging in speculation and conjecture ... [M]oreover, ... this medical testimony must at least be that the injury is 'probably' or 'more likely than not' caused the subsequent condition, rather than 'might have,' or 'possibly did' ... .[57]

As with plaintiffs in the US and in the UK, an Australian plaintiff must prove her case on the balance of probabilities: the 'more probable than not' standard. A standard greater than 50 per cent maximises the average number of correct decisions.[58] If this result, asserted to hold regardless of the shape of the probability distribution, were true, it still requires probabilistic and biologically accurate modelling. On occasions, a higher standard applies. Thus, for instance, in *Briginshaw v Briginshaw & Anor*,[59] Dixon J referred to "actual persuasion".[60] There is much confusion about probabilistic reasoning.

Justice Dixon's view illustrates a common misunderstanding. He states:[61]

> [Proof of a fact] cannot be found as a result of a mere mechanical comparison of probabilities independently of any belief in reality ... [T]he seriousness of an allegation made, the inherent unlikelihood of an occurrence of a given description, or the gravity of the consequences flowing from a particular finding are considerations which must affect the answer to this question ... .

Yet, these considerations are sensible when developed as probabilities. The 'mechanical' balancing (through, for example, Bayesian methods discussed in Part II), criticised by Dixon J, minimises injustice. That form of balancing is the kernel of legal 'unlikelihood',[62] 'gravity of the consequences' and 'consequences flowing'.

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56 Note 47 *supra* at 15057, citing *Daubert*, note 41 *supra* at 596.

57 *Orcutt v Spokane County*, 364 P 2d 1102 (1961) at 1105-06.

58 D Hamer, "The Civil Standard of Proof Uncertainty: Probability, Belief and Justice" (1994) 16 *Sydney Law Review* 506 at 509.

59 (1938) 60 CLR 336 at 361.

60 Supported in *Wintle v Conaust* [1989] VR 951 at 953, per Crockett and Gray JJ.

61 Note 59 *supra* at 361-2.

62 Presumably meaning the complement of the 'likelihood'.

Dixon J supported the principle that "as the offence is grave, so ought the proof be clear", criticised by Murphy J in *TNT Management v Brooks*[63] because it made the standard of proof subjective. Similarly, Lord Scarman's "high probability" commensurate with "what is at stake"[64] should be reversed when applied to the causal element of a toxic tort. We support the recent overruling of these precepts by the High Court in *Neat Holdings Pty Ltd v Karajan Holdings Pty Ltd.*[65] Increased stringency of the standard of proof borne by the plaintiff seems compelling if it fully disclosed the issues.[66] It is unjust, if it becomes a limiting device, because scientific knowledge changes rapidly and often remains uncertain. Good faith toxic tort plaintiffs can be denied compensation if forced to satisfy a higher standard.

The reason for this dissonance is that medical experts often state results as 'possibilities', insufficient legally to prove causation.[67] Although statistical 'medical certainty' in the courts has been set at 51 per cent, in science it is higher, from 95 per cent to 99 per cent, expressed in term of their complements, namely 0.05 to 0.01. Paradoxically, what a scientist regards as 'possible' can easily meet the required legal standard.[68] A single scientific study, even with a probability-value of 0.01 (99 per cent), can seldom, if ever, yield the legally required 'medical certainty' of causation. Moreover, the magnitude of the relative risk required to satisfy the 'more likely than not' standard is generally much greater than that found empirically in epidemiological studies proffered in toxic torts. Thus, even if a relative risk is greater than 1.0 and it is statistically significant (probability-value = 0.01) it still would not meet the 'more likely than not' standard. Indeed, the relative risk would have to be greater than 1.5.

In Australia, the precedent for scientific 'possibilities' is the judgment of Reynolds JA in *Fernandez v Tubemakers of Australia.*[69] He found that the courts have considerable discretion in deciding about possible cause, which depends on how much is known about the disease in issue. Thus, if little is known, evidence of 'possibility' carries little weight. If much is known, evidence of 'possibility' is accurate scientific opinion whose probative weight is determined by the trier of fact.[70]

The response, in the US, has vacillated. Some courts have differentiated between degrees of scientific certainty and 'legal sufficiency', using a lower standard than scientists, to establish legal causation.[71] Some courts held that the

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63 (1979) 53 ALJR 267.

64 *Khawaja v Secretary of State for the Home Department* [1984] AC 74

65 (1992) 67 ALJR 170 at 171.

66 See for example, *Blyth v Blyth* [1966] AC 643.

67 *Turpin v Merrell-Dow Pharmaceuticals* 959 F 2d 1349 (6th Cir 1992).

68 See DM Benjamin, "Elements of Causation in Toxic Tort Litigation: Science and Law Must Agree" (1993) 14 *Journal of Legal Medicine* 153.

69 [1975] 2 NSWLR 190 at 194.

70 *Ibid.* See also E Adeney, "The Challenge of Medical Uncertainty: Factual Causation in Anglo-Australian Toxic Tort Litigation" (1993) 19 *Monash University Law Review* 23 at 46-7.

71 See *Ferebee*, note 43 *supra* at 1536. The court held that absent epidemiological results, medical testimony and the appropriate scientific methods can serve as a substitute. See also *Wells v Ortho Pharmaceutical Corp* 788 F 2d 741 (11th Cir 1986); rehearing den'd 107 S Ct 437 (1986).

lesser standard should apply only to scientific facts.[72] Other courts shift the burden to the defendant and keep the 'more likely than not' test.[73] *Orcutt v Spokane County*[74] stated that:

> [T]he plaintiff must produce evidence to establish, with reasonable certainty, a causal relationship between the injury and the subsequent condition, so that the jury will not be indulging in speculation and conjecture ... [M]oreover, ... medical testimony must at least be that the injury "probably" or "more likely than not" caused the subsequent condition, rather than ... 'might have', or 'possibly did' cause the subsequent condition.

Unfortunately, 'probably' is not synonymous with 'more likely than not': the former encompasses a range of probabilities; the latter is any specific probability level, say 51 per cent.

Probabilistic evidence may fail the 'more likely than not' standard. Two views have emerged. The 'strong' version does not accept statistical measures of association without additional evidence of a "direct and actual knowledge of the causal relationship between the defendant's tortious conduct and the plaintiff's injury".[75] Direct evidence does not require inference. The 'weak' version is that statistical evidence suffices for inference.[76] The Agent Orange court stated that "particularistic evidence ... is no less probabilistic than...statistical evidence".[77] This court favoured the use of the 'strong' version of the standard for individual plaintiffs, but appeared to support the 'weak' version in class actions.[78] In the Agent Orange case, even using the 'preponderance of the evidence' test, statistically significant results may not result in liability. For example, the court[79] discussed a hypothetical in which 1000 cancers are expected and 1100 are found (assumed statistically significant). The court computed the individual's chance as 100/1100 (9 per cent), concluding that the plaintiff would therefore not recover because 9 per cent is below the 51 per cent required. The court devised a test where the preponderance of the evidence standard is not met if the alleged result falls within two standard deviations from the expected incidence of the disease. This was computed to be 31.6 excess cancers: the 100 excess cancers would meet this version of the 'preponderance of the evidence'.

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72 The Note, "Tort Actions for Cancer: Deterrence, Compensation, and Environmental Carcinogenesis" (1981) 90 *Yale Law Journal* 841, discusses the reluctance of the judiciary to modify the legal proof of causation to reflect scientific causation.

73 See *Gardner v National Bulk Carriers* 310 F 2d 284 (4th Cir 1962); cert den'd 372 US 913 (1963) and *Evers v Dollinger* 471 A 2d 405 (1984).

74 364 P 2d 1102 (1961) at 1105-06.

75 D Rosenberg, "The Causal Connection in Mass Exposure Cases: A 'Public Law' Vision of the Tort System" (1984) 97 *Harvard Law Review* 851 at 870.

76 *Ibid* at 870.

77 *In Re "Agent Orange" Product Liability Litigation* 597 F Supp 740 (EDNY 1984) at 836.

78 *Ibid.*

79 *Ibid* at 837, where statistically insignificant results are not fatal to the plaintiff's case.

IV. 'BUT FOR' AND 'COMMON SENSE'

TNT Management Pty Ltd v Brooks[80] concerned the attribution of responsibility for an accident in which there were no surviving eyewitnesses. Murphy J (minority on this issue) advocated the use of probabilistic reasoning because, although actual individual liability remains unknown, it ensures *objective* reasoning in cases with uncertain causation. However, his view has not been adopted in subsequent Australian decisions which prefer reasoning by 'common sense'. Thus, in *Bennett v Minister of Community Welfare*,[81] the High Court followed the majority in *March v E & MH Stramare Pty Ltd*[82] holding that:

> In ... negligence, causation is essentially a question of fact, to be resolved as a matter of common sense. In resolving that question, the "but for" test, applied as a negative criterion of causation, has an important role to play but it is not a comprehensive and exclusive test of causation; value judgments and policy considerations necessarily intrude.[83]

Supplementing the 'but for' test with 'common sense' and 'policy' is pragmatism. However, the law can no longer dictate that, unless the injury can be predominantly attributed to one source (that is, unless it can be *shown* that the injury would not have occurred 'but for' that source), recovery is impossible.[84] *Wintle v Conaust* illustrates the issue relative to the toxic tort plaintiff.[85] Here, a wharf worker exposed to asbestos by five employers had medical evidence that his mesothelioma, a rare cancer causally associated with asbestos, was caused by asbestos exposures. Since mesothelioma background rates are almost zero, there was little doubt that the plaintiff's employment caused his illness. It could not, however, be attributed to any single employer. The plaintiff failed because, although one or more of the five respondents had caused the disease, none could be liable. The plaintiff had to satisfy 'but for' causation relative to a single defendant.

This result of traditional tort law is inequitable for plaintiffs. When medical evidence is not sufficiently advanced to identify one 'but for' defendant, or because the disease may have been caused by cumulative exposure from multiple sources, the standard becomes unjust. *Wintle* is especially troublesome because there was an equal breach of the duty of care by all defendants.[86] Arguably,

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80 Note 63 *supra*.

81 (1992) 176 CLR 408.

82 (1991) 171 CLR 506.

83 *Ibid* at 519, per Mason CJ, Deane and Toohey JJ. Notably, while McHugh J in *March v Stramare* (*ibid* at 533) expressed concern about "subjective, unexpressed and undefined extra-legal values to determine liability", in *Bennett* (note 81 *supra*) he joined with the majority. For details of the High Court's treatment of causation see A Palmer, "Causation in the High Court" (1993) 1 *Torts Law Journal* 9.

84 Mason CJ in *March v Stramare* recognised that the "but for" test was especially inadequate in cases of multiple sufficient causes: *ibid* at 516.

85 [1989] VR 951. This case, and the similarity of reasoning of *Bryce v Swan Hunter Group* [1988] 1 All ER 659, are fully discussed in E Adeney, note 70 *supra* at 43-5.

86 Gaudron J suggested in *Bennett* that breach of duty might not be separated from causation: note 81 *supra* at 626. See A Corbett, "A Reformulation of the Right to Recover Compensation for Medically Related Injuries in the Tort of Negligence" (1997) 19 *Sydney Law Review* 141.

Bennett's common sense and public policy would preclude this outcome. Nevertheless, the 'but for' principle must be expanded to include the contribution[87] or the attribution of liability through probability of causation methods. This is critical particularly because the level of epidemiological (and biological) knowledge available for dose-response between mesothelioma and asbestos is seldom available in toxic torts.

A. Common Sense Versus Probabilistic Reasoning

The danger of allowing policy to predominate in decisionmaking, at the expense of probabilistic reasoning, is demonstrated by a test Adeney calls "harm-within-the-risk".[88] It emphasises the common sense connection between injury and the defendant's negligent conduct.[89] This test, not followed in Australia, was developed by Lord Reid in *McGhee v National Coal Board*, where he commented that:

> it has often been said that the legal concept of causation is not based on logic or philosophy. It is based on the practical way in which the ordinary man's mind works in the everyday affairs of life.[90]

If the defendant tortiously created a risk harming the plaintiff within the scope of the risk, the plaintiff could receive full recovery. However, without probabilistically-weighted scientific evidence (demanded by 'risk') it is impossible to tell if a causal association exists between that increased risk and injury.

For instance, consider the situation where there is a 30 per cent background risk, and a 45 per cent risk after the negligent act, there is a 15 per cent chance of contracting the disease from negligence and a 30 per cent chance of contracting it from background. With the 'harm-within-the-risk' test, the plaintiff would fully recover,[91] but it is unfair to a defendant who would prevail under the 'more likely than not' test.

Australian courts have tempered the draconian effect of the 'but for' test using a subjective test based on ill-defined notions of 'material contribution'.[92] This is the principle that a defendant's negligence may be legal cause if it materially contributes to a plaintiff's injury. 'Materially' means that the evidence introduced on a disputed fact is within the 'range of controversy': it is an additional requirement to the 'probative' aspect of that evidence.

The traditional 'all or nothing' rule gives full recovery to those plaintiffs who, inter alia, prove legal causation. Plaintiffs who partly demonstrate causation fail. If the defendant's negligence was a material cause of the damage, and all

87 See *Thompson v Johnson and Johnson Pty Ltd* (1989) Aust Torts Reports 80-278.

88 E Adeney, note 70 *supra* at 48-54.

89 R Wright, "Causation in Tort Law" (1985) 73 *California Law Rev* 1735 at 1763-6.

90 [1973] 1 WLR 1 at 5.

91 From E Adeney, note 70 *supra* at 50, who gives the example of the dust-covered workman, the factual scenario in *McGhee*.

92 The idea that a defendant's negligence is causal if it materially contributed to a plaintiff's injury, particularly by adding to the risk of injury, has been followed in a number of Australian cases. See *Chance v Alcoa of Australia Ltd* (1990) Aust Torts Reports 80-017 and *Thompson v Johnson and Johnson Pty Ltd & Anor* (1991) Aust Torts Reports 81-075. Also see E Adeney, note 70 *supra* at 29-38.

sufferers brought actions, the result would be the same as for the 'harm-within-the-risk' test. That is, all plaintiffs would recover although background factors were responsible for injuring only a proportion of them. However, if damage was immaterial, no plaintiff would recover despite the fact that it is just as certain that the defendant injured some of the plaintiffs. Thus, the 'material contribution' test is unsatisfactory unless it is linked to a probabilistic and phenomenological framework objectively to establish what is 'material'.

The difficulties of attributing an illness to exposure cannot be underestimated. The difference between background risk and added risk from exposure is, if based on population data, an aggregate over several individuals. Therefore, absent one or more variables that indicate the unique attribution of the added risk to one or more individuals, who may not be before the bench, it is impossible to assign the excess risk to the plaintiffs. Although aggregate (population) data suggests the *existence* of causation, the inclusion of suitable explanatory random variables particularise the uniqueness of the alleged adverse effect.[93]

Thus, there can be injustice when the 'common sense' test is applied when causation in fact and proximate are probabilistic. Seeming ease of judicial use does not outweigh the benefits for the plaintiffs, where there are multiple and sufficient causes.[94] When the results claimed to justify the common sense approach can be achieved, in cases of multiple sufficient causes, by an objective test such as the Necessary Element of a Sufficient Set (NESS) test, the common sense test is as unjustified as it is expedient.

B. "Necessary Element of a Sufficient Set" (NESS) Test

This test has introduced the basis of probabilistic causation in some Australian courts. It allows "for the creation of a *set of conditions* which was *sufficient on its own* to produce the injury".[95] This concept recognises complexity and probabilities. It is both a movement away from the deterministic and linear 'but for' causation and an attempt to incorporate proximate cause within the notion of sufficiency. Since this test provides a mechanism for formally analysing multiple sufficient causes it applies to diseases in which response results from diverse sources of exposure. These are, by themselves, necessary to cause injury but often insufficient to do so.

Take a plaintiff who is exposed to one unit of a toxic chemical by each of four employers. Medical evidence can demonstrate that three units of exposure were required to cause the injury now suffered by the plaintiff. Each employer may argue that his or her single unit of exposure was neither necessary nor sufficient to cause the injury and, under the *Wintle* test, recovery is denied because no single and unique defendant caused the injury. However, using the NESS test,

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93 The egg-shell or thin-skull theory, *Keegan v Minneapolis & St Louis RR Co*, 78 N W 965 (Minn 1899) and *Dulieu v White* 2 KB 669 (1901) is an exception to foreseeability: the defendant takes the plaintiff as she finds him. It has extended to nervous shock in American jurisdictions and in the UK: *Steinhauser v Hertz Corp*, 421 F 2d 1169 (2d Cir 1970) and *Malcom v Broadhurst* (1970) 3 All ER 508.

94 In the context of modelling and data, model X is sufficient for the data Y, and Y is necessary for X. In other words, X implies Y: X is 'sufficient condition for Y' and Y is 'necessary condition for X'.

95 E Adeney, note 70 *supra* at 28 (emphasis added).

each defendant *is* a contributory cause of that injury, as each is "necessary for the sufficiency of *a* set of actual antecedent conditions" which, in this case, includes only two of the other several units. The additional unit is irrelevant on sufficiency.[96] The plaintiff can recover for the injury done to her by the joint negligent acts of multiple defendants. The generalisability of the NESS test supports establishing legal causation for toxic tort litigation. Although the NESS test is a convenient way to analyse evidence of multiple causes, linking an increased risk to an individual plaintiff remains problematic.

V. REDEFINING INJURY

The present (physical) injury requirement of tort law must be redefined. One way is to broaden the definition of injury-in-fact. Thus, fear of serious or dreaded injury developing in the future can be sufficient effect, instead of requiring a plaintiff to wait until a latent disease clinically becomes manifest.[97] The second is to allow recovery for future physical injury. The central issue is *probable future* injury. It is antithetic to the precept that compensation, in tort law, requires *present* injury.[98] The redefinitions of injury beyond the orthodox requirements are increasing. For instance, chromosomal damage was sufficient "present injury" in an emotional distress claim.[99] Other jurisdictions allowed emotional distress recovery without physical injury, but required injury for a claim based on increased risk.[100] Others yet, although there are no physical injuries in those at increased risk, allowed the claim.[101]

A. Loss of Chance

In an action for loss of chance of survival, a plaintiff need not prove that the negligent defendant caused her injury. Rather, she argues that the defendant's breach of a legal duty (or an omission) deprived her of the chance of a normal and more advantageous outcome.

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96 This example was adapted from R Wright, note 89 *supra* at 1793-4 who explains the development, extent and advantages of the NESS test in detail.

97 In toxic tort cases involving cancer and asbestosis, which take years to manifest, a plaintiff is unable to claim for damage until injuries are detectable, despite the emotional distress that undoubtedly accompanies knowledge of deleterious exposure.

98 *Amendola v Kansas City So RR Co*, 699 F Supp 1401 (W D Mo, 1988) (asbestos exposure without showing of asbestos related physical injury led to summary judgment against the plaintiff).

99 *Brafford v Susquehanna Corp*, 586 F Supp 14 (D Co 1984) (radiation exposure to levels in excess of US federal limits associated with chromosomal damage is present physical injury for the purpose of an action based on increased risk of cancer).

100 *Eagle-Picher Industries Inc v Cox*, 481 So 2d 517 (Fla App 3 Dist 1985) (increased risk of cancer insufficient from asbestos exposure, but plaintiff's asbestosis was present injury for the claim of emotional distress).

101 *Sterling v Velsicol Chemical Corporation*, 855 F 2d 1188 (6th Cir, 1988) (the 25 to 30 per cent increased risk of cancer did not meet the "reasonable medical certainty" test and was only a "possibility" of cancer. However, the exposure was sufficient to support a claim of fear of cancer).

In the United States, it was assumed that the loss of chance doctrine[102] should lower the burden of proving causation.[103] Adeney argued that:[104]

> it should be possible to prove causation not of the medical condition suffered by the plaintiff but of the loss of that plaintiff's chance of a better outcome. ... the defendant's breach caused the risk of an unfavourable outcome to be increased above background ....

The High Court held, in *Johnson v Perez*[105] and *Malec v JC Hutton Pty Ltd*,[106] that damages may be awarded for loss of chance resulting from a tort, but it remains to be seen how comprehensively this doctrine will be followed in Australia. Consider the judgment of Brennan J in *Sellars v Adelaide Petroleum NL*.[107] This was a claim for loss of commercial opportunities resulting from reliance on the misrepresentation by the defendant. Brennan J stated:

> The loss of a mere opportunity to acquire a benefit is not in itself a loss, but the loss of the benefit will be ... a loss if the plaintiff proves that he could ... have taken the opportunity and that the benefit would have been yielded.[108]

By analogy to *Sellars'* case, the plaintiff, because of the defendant's negligence, must prove that exposure legally caused her to lose the opportunity of remaining healthy.[109] Moreover, the original chance of remaining healthy must also be proven on the balance of probabilities.[110] This suggests that the cause of action does not accrue unless the condition develops.[111]

The difficulties of accurately detailing health-related 'loss of the chance' may explain why Australian courts limit it to the loss of opportunity to attain a commercial benefit.[112] Indeed, in *Sellars'* case, the High Court qualifies its ratio decidendi consistently by reference to commercial opportunities,[113] and it is reluctant to discuss that theory in medical cases.[114]

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102 In the US, the doctrine is called "lost chance".

103 JH King, "Causation, Valuation and Chance in Personal Injury Torts Involving Preexisting Conditions and Future Consequences" (1981) 90 *Yale Law Journal* 1353; Note, "Medical Malpractice: the fight to recover for a loss of a chance of survival" (1985) 12 *Pepperdine Law Review* 973; *Perez v Las Vegas Medical Centre*, 805 P 2d 589 (Nevada 1991); *Falcon v Memorial Hospital*, 462 NW 2d 44 (1990).

104 E Adeney, note 70 *supra* at 63.

105 (1988) 166 CLR 351.

106 (1990) 169 CLR 638.

107 (1994) 179 CLR 332.

108 *Ibid* at 362.

109 In *Wilsher v Essex Area Health Authority* [1988] 1 AC 1974, the court held that there were so many factors that could have led to the baby's blindness that the administration of excess oxygen could not be attributed as the cause of his losing the chance of retaining his sight. To enable plaintiffs to overcome such a hurdle, a Royal Commission Report considered shifting the burden of proof to the defendant, but added that such shifts could be counterproductive forcing defensive medical practices.

110 In *Hotson v East Berkshire Area Health Authority* [1987] 1 AC 750 the House of Lords reversed the lower court holding that a 25 per cent increased risk was compensable.

111 G Masel, "Damages in Tort for Loss of Chance" (1995) 1 *Torts Law Journal* 43 at 49-52.

112 The loss of chance is the loss to acquire a benefit through another transaction that would have been undertaken had the plaintiff not relied on the defendant's tortious conduct. See *Chaplin v Hicks* (1911) 2 KB 786 calculating damages at their expected value.

113 See especially, note 107 *supra* at 355.

114 In *Sullivan v Micaleff* (1994) Aust Torts Reports 81-308, the New South Wales Court of Appeal decided the case on the basis of ordinary principles of causation, as the balance of probabilities test could be satisfied.

B. Increased Risk of Future Injury

This doctrine has not been followed in Australian cases, but is applied in the United States.[115] The prototypical case involved women prenatally exposed to diethylstilboestrol (DES), used to prevent miscarriages and later associated with clear-cell adenocarcinoma.[116] The relative risk for the mothers who took DES was sufficiently high for causation to be uncontroverted. Additionally, the daughters of those mothers were at increased risk of cancer because of their mothers' exposure.

Despite much litigation, recovery was rare.[117] Such increased risk cases have failed because they were too 'speculative', or that the likelihood of future injury given by the experts were qualitative and did not meet the 51 per cent standard. Nevertheless, in some cases, the courts awarded general damages for diminished quality of life and granted medical surveillance costs.[118] These were attempts to cope with difficult causation (the relationship between the mothers' use of DES and the daughters' probable cancer) that would prevent recovery.

C. Fear of Future Injury

In Australian law, anxiety, fear and other emotional distress, known as nervous shock, are compensable only if they are either psychiatric illness, or psychiatric or psychological disorders.[119] However, as demonstrated by *Coates v GIO (NSW)*,[120] where two children suffered severe grief reactions when told of the death of their father, the distinction between normal grief and psychiatric illness is difficult to make, and the law is conservative. Kirby P, departs from misplaced conservatism. He stated that:

> One might criticise the scarcely delineated distinction made between grief and suffering following tragic news and psychological or psychiatric injury...[N]ineteenth century notions of psychological illness and an abiding suspicion of such claims ... forbid recovery where prolonged grief is shown ... . To adhere to stereotypes expressed in terms of "abnormal grief" derived from England, may work an injustice upon Australian litigants for whom the norms are different... .[121]

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115 PF Ricci and LS Molton, "Increased Risk in U.S. Law" in G Apostolakis (ed), *Probability Safety Assessment*, Elsevier (1991).

116 Approximately two million young women were given DES to prevent miscarriages from 1947 to 1971. See H Scully, "Adenocarcinoma of the Vagina in Adolescence, a report of 7 cases including 6 Clear-Cell Carcinomas" (1970) 25 *Cancer* 745.

117 See for example, *Chernosky v Abbott Laboratories* 22765 (Sup Ct, NY Co 1994) where the jury award was for US $42,000,000.00 (awarded at the close of the jury trial in January 1994). The apportionment of liability, however, resulted in only 2 defendents being liable for about 1 per cent of the award and the other for about 5 per cent. Settlements took care of the 95 per cent.

118 See *Ayers v Township of Jackson* 525 A 2d 287 (NJ 1987). The court determined that some cellular damage (but not frank medical endpoints) had occurred and allowed medical surveillance to guard against "possible" increased risks of future diseases.

119 *Jaensch v Coffey* (1984) 155 CLR 549.

120 (1995) 36 NSWLR 1.

121 *Ibid* at 12.

Another traditional requirement is that the emotional distress must have physical symptoms; recovery for the former is 'parasitic' relative to the latter.[122] In Australia, the requirement of actual physical injury has been relaxed in several toxic tort cases, including *Napolitano v CSR Ltd*[123] where the plaintiff's fear of asbestosis, occurring before any physical disability was diagnosed, was compensable illness.

The California Supreme Court held, in *Potter v Firestone Tire & Rubber Co*,[124] that if "fear stems from a knowledge, corroborated by reliable medical and scientific opinion, that it is more likely than not that the feared cancer will develop in the future due to toxic exposure" then recovery is permissible.[125] Recovery occurs only if the plaintiff proves "knowledge that there is a probable likelihood of developing cancer in the future due to the toxic exposure".

What is "probable likelihood"? We take that it is the probability of an event conditioned on an experimental data that has a quality that "might cautiously [be] called 'objectivity'".[126] This probability is the likelihood. Then, we take it that the subjective probability, before the data are available and "usually conspicuously personal and vague",[127] is what *Potter* means by "probable". Consequently, *Potter's* 'probable likelihood' test[128] is the Bayesian apparatus which will be set out in Part II. What is left out is the actual magnitude of the 'probable likelihood'.

Potter asks whether "it is reasonable for a person to genuinely and seriously fear a disease that is not probable",[129] and whether such a person should receive legal compensation. The court does not exclude that eventuality, stating that:

> we would be very hard pressed to find that, as a matter of law, a plaintiff faced with a 20 percent or 30 percent chance of developing cancer cannot genuinely, seriously and reasonably fear the prospect of cancer. Nonetheless, ... for the policy reasons, ... emotional distress caused by the fear of cancer that is not probable should generally not be compensable ... .[130]

Potter denies those claims because of the "tremendous social cost" that they, otherwise admittedly justifiable, would cause.[131] It seeks a "sufficiently definite and predictable threshold for recovery to permit consistent application from case to case."[132] The court equates the 'more likely than not' standard with 'probable

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122 See in general, H Luntz, "Fear of disease as damage in negligence: the view of the Supreme Court of California" (1995) 3 *Torts Law Journal* 212.

123 Unreported WA(SC), Seaman J, 30 August 1994. See also *Commonwealth of Australia v Dinnison* (1995) 129 ALR 239.

124 93 CDOS 9695 (1993); 863 P 2d 795; 25 Cal Reptr 2d 550 (reversing and remanding a judgment for the plaintiff for emotional distress due to fear of cancer).

125 *Potter*, note 124 *supra* at 9695-6.

126 Following Savage, caution is due to probabilities being defined as "expressions of opinion": LJ Savage, *The Foundations of Statistical Inference: A Discussion*, Methuen & Co Ltd (1962), p 16.

127 *Ibid.*

128 *Potter*, note 124 *supra*, at 9700, asks for an "actual likelihood" that the fear and the cancer are associated to be sure that the plaintiff's claim is reasonable.

129 *Ibid* at 9700, where the court means "more likely than not" or its logic would be faulty.

130 *Ibid.*

131 The court reasons that "meaningful restrictions" should curb litigation, otherwise the insurance market would raise its premiums making insurance impossible to obtain: *ibid* at 9701.

132 *Ibid.*

likelihood'. This is incorrect. First, the threshold ('probable likelihood') can be any (posterior) probability value. Second, the court asks for, but does not provide, the magnitude of the threshold. It states that a "2 or 5 percent likelihood of future illness" may lead a jury to find for the plaintiff and it is against such eventuality.[133] But is not 2 per cent as definite a "probable likelihood" as 51 per cent? And what is this standard? We turn to this next.

Judicial Inconsistency

The search for a judicially consistent threshold seems doomed, as *United States v Fatico*[134] suggests. There, Judge Weinstein polled several fellow judges to determine what numbers those judges would assign to four legal tests (from the 'preponderance of the evidence' to 'beyond a reasonable doubt'). The results speak for themselves:[135]

Judge number	Preponderance of the evidence (%)	Clear and convincing (%)	Clear, unequivocal, and convincing (%)	Beyond a reasonable doubt (%)
1	50+	60-70	65-75	80
2	50+	67	70	76
3	50+	60	70	85
4	51	65	67	90
5	50+	Elusive*	Elusive*	90*
6	50+	70+	70+	85
7	50+	70+	80+	95
8	50.1	75	75	85
9	50+	60	90	85
10	51	Not estimable**	Not estimable**	Not estimable**

* "Standard is elusive and unhelpful"
** "Cannot estimate numerically"

Although non-quantitative considerations structure judicial decisions, it is perplexing that in this small sample of federal trial judges there is incoherence among the probability value of fundamental legal tests. The narrow differences suggest that these judges discriminate within the range 60-70 per cent and 65-75 per cent (judge 10) or between 67 and 70 per cent (judge 2) because of the overlap between the two ranges and the percentage difference. Is this realistic? Furthermore, two judges do not provide a numerical answer: thus "elusive" and

133 *Ibid.*

134 458 F Supp 338 (SDNY, 1978)

135 The original Table is "Probabilities Associated with Various Standards of Proof Judges in the Eastern District of New York", *ibid* at 410. In that Table, the percentage sign is included after each numerical value (unless unnecessary); for convenience we added the % sign in the headings, but omitted it next to the numerical value.

"not estimable" are used instead. How can a just balancing occur when the fulcrum is "elusive" or "not estimable"? Finally, because of semantic fuzziness, the wrong test may be used unwittingly.[136]

The *Fatico* court explains why these standards are not well quantified. It cites Wigmore's statement that "no one has yet invented ... a mode of measurement for the intensity of human belief".[137] It quotes Starkie's questioning how "moral probabilities could ever be represented by numbers ... and thus subjected to arithmetical analysis ... ."[138] and contrasts these with Bentham's use of number to establish degrees of belief.[139]

The court's justification is inchoate. It is of little consolation that the court in *Potter* adopts a *lesser* standard than negligence for the plaintiff to overcome.[140] Thus, per *Potter*:[141]

> a toxic exposure plaintiff need not meet the more likely than not threshold for fear of cancer ... if the plaintiff pleads and proves that the defendant's conduct in causing the exposure amounts to 'oppression, fraud, or malice' ... .

The callousness of a defendant's action shifts (on the X-axis, measured between 0 and 1) the 'threshold' to the left of the 'more likely than not'. However, confidence in the overall causal chain, measured between 0 and 1 on the Y- axis can decrease, depending on the facts and the completeness of the causal chain, as the numerical value of the test is relaxed. Setting up the causal process and assessing it probabilistically avoids ex post facto rationalisations. Each fact pattern will have different likelihoods and prior beliefs. This construct transparently accounts for the totality of the factual events and their mechanistic (in the epistemological sense) connections. Judicial 'proximate cause', a stopping rule, could be predicated on the 'knew or should have known' principle.

VI. CONCLUSIONS

As toxic tort litigation in Australia increases,[142] the question of who should be compensated will require a clearer process for deciding causation on the basis of uncertain and complex scientific evidence. This Part of this paper has identified the scientific and legal problems that affect causation in cases involving probabilistic scientific evidence, and has developed some approaches to overcome them. The complexities and uncertainties exceed the ordinary experience of lay fact finders and cannot be dealt with adequately by simplistic notions of 'common sense'.

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136 JL Gastwirth, "Statistical Reasoning in the Legal Setting," (1992) 46 *The Am Statistician* 55 at 56-7.

137 Note 134 *supra* at 411, citing JH Wigmore, *Evidence*, (3rd ed 1940) § 2497, p 325.

138 *Ibid*, citing T Starkie, *Law of Evidence*, Sharswood (9th Am ed, 1869), pp 753-4.

139 *Ibid*, citing J Bentham, *Rationale of Judicial Evidence*, (1827) Ch VI, p 71 ff.

140 The court uses "aggravated conduct" to differentiate the reason for the differential treatment: note 124 *supra* at 9703.

141 *Ibid*.

142 W Blacker, "Benzodiazepine Proceedings Struck Out" (1995) 6 *Australian Product Liability Reporter* 105.

This is not to say that lay persons cannot deal with scientific evidence. Rather, what is required is formal and coherent analysis and synthesis of evidence leading to causation to enhance the fact finders' understanding. One such method, based on conditional probabilities, is plausible and well established and, within the context of a formal system, is discussed in Part II. We also justify the choice of a formal and coherent method as a means to achieve the symmetrical treatment of information between the parties. Following Samuelson and others, we also justify our views because holding private information in certain types of negotiations and bargains[143] is inefficient.

Australian law is currently unable to adequately utilise formal reasoning under uncertainty in toxic torts. As shown, most of the alternative judicial tests developed by the common law are fuzzy. Although there have been attempts to recognise the centrality of probabilistic techniques in analysing uncertain scientific evidence, no one has suggested a prescriptive approach to its utilisation.

Toxic tort law can benefit from formal decisionmaking that transparently and replicably characterises incomplete knowledge, uncertainty and variability by propagating and summarising it. We have laid the foundations to do so and justified them. What is now required is further work towards a process that maintains and divulges assumptions and that can use alternative measures of uncertainty that are flexible and consultative. This would increase the neutrality of access to scientific information, enhancing social dialogue and legal fairness. Until this occurs, Australian tort law will remain unable to adequately yield just outcomes in toxic tort cases.

143 PA Samuelson, "Bargaining Under Asymmetric Information" (1984) 52 *Econometrica* 995; AE Roth (ed), *Game-Theoretic Models of Bargaining*, Cambridge University Press (1985).