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Reference Manual on Scientific Evidence

Second Edition

Federal Judicial Center 2000

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Preface

Thomas Henry Huxley observed that “science is simply common sense at its best; that is, rigidly accurate in observation and merciless to a fallacy in logic.”¹ This second edition of the *Reference Manual on Scientific Evidence* furthers the goal of assisting federal judges in recognizing the characteristics and reasoning of “science” as it is relevant in litigation. The *Reference Manual* is but one part of a series of education and research initiatives undertaken by the Center, in collaboration with other professional organizations, and with support by a grant from the Carnegie Corporation of New York, to aid judges in dealing with these issues. The *Reference Manual* itself responds to a recommendation of the Federal Courts Study Committee that the Federal Judicial Center prepare a manual to assist judges in managing cases involving complex scientific and technical evidence.²

The first edition of the *Reference Manual* was published in 1994, at a time of heightened need for judicial awareness of scientific methods and reasoning created by the Supreme Court’s decision in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*³ *Daubert* assigned the trial judge a “gatekeeping responsibility” to make “a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid and of whether that reasoning or methodology properly can be applied to the facts in issue.”⁴ The first edition of the *Reference Manual* has been republished by numerous private publishers and used in a variety of educational programs for federal and state judges, attorneys, and law students. The Center estimates that approximately 100,000 copies have been distributed since its initial publication.

This second edition comes after recent decisions that expand the duties and responsibility of trial courts in cases involving scientific and technical evidence. In *General Electric Co. v. Joiner*,⁵ the Supreme Court strengthened the role of the trial courts by deciding that abuse of discretion is the correct standard for an appellate court to apply in reviewing a district court’s evidentiary ruling. In a concurring opinion, Justice Breyer urged judges to avail themselves of techniques, such as the use of court-appointed experts, that would assist them in

1. T.H. Huxley, *The Crayfish: An Introduction to the Study of Zoology* 2 (1880), quoted in Stephen Jay Gould, *Full House: The Spread of Excellence from Plato to Darwin* 8 (1996).

2. Federal Courts Study Comm., Report of the Federal Courts Study Committee 97 (1990). See also Carnegie Comm’n on Science, Tech., & Gov’t, *Science and Technology in Judicial Decision Making: Creating Opportunities and Meeting Challenges* 11 (1993) (noting concern over the ability of courts to manage and adjudicate scientific and technical issues).

3. 509 U.S. 579 (1993).

4. *Id.* at 589 n.7, 592–93.

5. 522 U.S. 136, 141–43 (1997).

making determinations about the admissibility of complex scientific or technical evidence.⁶ Last year, in *Kumho Tire Co. v. Carmichael*, the Supreme Court determined that the trial judge's gatekeeping obligation under *Daubert* not only applies to scientific evidence but also extends to proffers of "'technical' and 'other specialized' knowledge," the other categories of expertise specified in Federal Rule of Evidence 702.⁷ Also, the Supreme Court recently forwarded to Congress proposed amendments to Federal Rules of Evidence 701, 702, and 703 that are intended to codify case law that is based on *Daubert* and its progeny.

This second edition includes new chapters that respond to issues that have emerged since the initial publication. The Introduction by Justice Breyer reviews the role of scientific evidence in litigation and the challenges that trial courts face in considering such evidence. Supreme Court cases subsequent to *Daubert* are summarized in a chapter by Margaret Berger. The philosophy and practice of science are described in a chapter by David Goodstein. New reference guides on medical testimony and engineering will aid judges with the broader scope of review for cases involving nonscientific expert testimony following *Kumho*. Reference guides from the first edition have been updated with new cases and additional material. The Reference Guide on DNA Evidence has been completely revised to take account of the rapidly evolving science in this area. To make room for the new material, essential information from the chapters on court-appointed experts and special masters was condensed and included in the chapter on management of expert evidence.⁸

We continue to caution judges regarding the proper use of the reference guides. They are not intended to instruct judges concerning what evidence should be admissible or to establish minimum standards for acceptable scientific testimony. Rather, the guides can assist judges in identifying the issues most commonly in dispute in these selected areas and in reaching an informed and reasoned assessment concerning the basis of expert evidence. They are designed to facilitate the process of identifying and narrowing issues concerning scientific evidence by outlining for judges the pivotal issues in the areas of science that are often subject to dispute. Citations in the reference guides identify cases in which specific issues were raised; they are examples of other instances in which judges were faced with similar problems. By identifying scientific areas commonly in dispute, the guides should improve the quality of the dialogue between the judges and the parties concerning the basis of expert evidence.

6. *Id.* at 147–50.

7. 119 S. Ct. 1167, 1171 (1999) (quoting Fed. R. Evid. 702).

8. Much of the information in those two chapters is available in Joe S. Cecil & Thomas E. Willging, *Accepting Daubert's Invitation: Defining a Role for Court-Appointed Experts in Assessing Scientific Validity*, 43 Emory L.J. 995 (1994), and Margaret G. Farrell, *Coping with Scientific Evidence: The Use of Special Masters*, 43 Emory L.J. 927 (1994).

Reference Manual on Scientific Evidence

This Reference Manual was begun and furthered by two of my predecessors, Judge William W Schwarzer and Judge Rya Zobel. Their work in developing the Center's program on scientific evidence established the foundation for the Center's current initiatives. In developing the *Reference Manual* we benefited greatly from the encouragement and support of David Z. Robinson, former executive director of the Carnegie Commission on Science, Technology, and Government, and Helene Kaplan, chair of the Commission's Task Force on Judicial and Regulatory Decision Making. A number of persons at the Center have been instrumental in developing this second edition of the *Reference Manual*. Joe Cecil and Dean Miletich served as editors of the *Reference Manual*. They profited from the advice and assistance of the following members of the Center's Communications Policy & Design Office: Geoffrey Erwin, Martha Kendall, Kris Markarian, and David Marshall. Rozzie Bell of the Center's Information Services Office offered great assistance in locating much of the source material. Finally, we are grateful to the authors of the chapters for their dedication to the task, and to the peer reviewers of the chapters for their thoughtful suggestions.

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Reference Guide on Medical Testimony

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I. Introduction

Testimony by physicians is one of the most common forms of expert testimony in the courtroom today.¹ Medical testimony is routinely offered in both civil and criminal cases, including assault and battery,² rape,³ workers' compensation proceedings,⁴ and personal injury suits.⁵ In the civil arena alone, medical testimony is frequently offered as part of medical malpractice cases,⁶ Employee Retirement Income Security Act (ERISA) suits on coverage of health care plans,⁷ Americans with Disabilities Act litigation,⁸ product liability suits,⁹ and toxic injury cases, such as breast implant and environmental contamination claims.¹⁰ In

1. Samuel R. Gross, *Expert Evidence*, 1991 Wis. L. Rev. 1113, 1119 (a survey of trials revealed that over half of the testifying experts were physicians or medical professionals). Two unpublished surveys by the Federal Judicial Center, one in 1991 and another in 1998, found that physicians and medical experts comprised approximately 40 percent of the testifying experts in federal civil trials.

2. See *United States v. Drapeau*, 110 F.3d 618, 619–20 (8th Cir. 1997) (medical testimony of the examining doctor of the infant victim refuted the possibility that the child's injuries were the result of a fall from his bed); *United States v. Talamante*, 981 F.2d 1153, 1158 & n.7 (10th Cir. 1992) (physician testified that the victim's eye was not completely blind at the time of the assault, supporting a finding of serious bodily injury).

3. See *United States v. Pike*, 36 F.3d 1011, 1012–13 (10th Cir. 1994) (in a case of sexual abuse of a minor, the testimony of the examining physician need not be preferred over the testimony of the victim where the physician's testimony neither supports nor refutes the victim's testimony).

4. Medical testimony will almost always be offered on the diagnosis of the plaintiff's injury or disease, and often on other issues as well. See *Silmon v. Can Do II, Inc.*, 89 F.3d 240, 241 (5th Cir. 1996) (testimony of three doctors as to the cause of the plaintiff's ruptured disc; the employer denied liability under the Jones Act, alleging that the plaintiff's injury was caused by illegal intravenous drug use); *Bertram v. Freeport McMoran, Inc.*, 35 F.3d 1008, 1018 (5th Cir. 1994) (upholding the district court's discretion to give greater weight to the medical testimony of the plaintiff's primary treating physician where the plaintiff sued under the Jones Act for injuries arising from a workplace accident on a drilling barge).

5. See *DiPirro v. United States*, 43 F. Supp. 2d 327, 331–39 (W.D.N.Y. 1999) (recounting the court's findings of fact based upon the testimony of five physicians for the plaintiff and five physicians for the defendant concerning plaintiff's alleged injuries caused by an accident involving a U.S. Postal Service vehicle).

6. See *Murray v. United States*, 36 F. Supp. 2d 713, 716 (E.D. Va. 1999) (plaintiff's expert medical witness testified that the care provided fell well below that standard applicable to emergency room physicians).

7. See *Dodson v. Woodmen of the World Ins. Soc'y*, 109 F.3d 436, 438 (8th Cir. 1997) (treating physician testified that the plaintiff was mentally disabled prior to the expiration of his ERISA policy).

8. *Price v. National Bd. of Med. Exam'rs*, 966 F. Supp. 419 (S.D. W. Va. 1997) (medical testimony offered as to whether plaintiff had attention deficit hyperactivity disorder that caused disability as defined by the Americans with Disabilities Act).

9. See *Demaree v. Toyota Motor Corp.*, 37 F. Supp. 2d 959 (W.D. Ky. 1999) (plaintiff's examining physician testified regarding injuries allegedly caused by a deploying air bag); *Toole v. McClintock*, 999 F.2d 1430, 1431 & n.2 (11th Cir. 1993) (reporting that five surgeons, including the plaintiff's treating physician, testified regarding surgery that caused breast implant rupture).

10. See *Satterfield v. J.M. Huber Corp.*, 888 F. Supp. 1567, 1571 (N.D. Ga. 1995) (plaintiff's doctors testified that the plaintiff's symptoms were also consistent with exposure to secondary sources of

many instances, medical testimony or medical evidence is an indispensable part of the inquiry.

A. *Applicability of Daubert v. Merrell Dow Pharmaceuticals, Inc.*

Since the U.S. Supreme Court issued its opinion in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*,¹¹ many courts have assessed the reliability of medical testimony according to *Daubert's* standards. More recently, in *Kumho Tire Co. v. Carmichael*,¹² the Court held that *Daubert's* reliability requirement and the trial judge's gatekeeping role apply to all expert testimony.

Although *Kumho* resolved any uncertainty as to the applicability of *Daubert's* standards to medical testimony, there is still uncertainty over *how* courts will apply these standards, given the different approaches taken by the courts to consideration of the admissibility of medical evidence.¹³ Two recent cases illustrate this diversity. In *Moore v. Ashland Chemical, Inc.*,¹⁴ a case decided before *Kumho* that applied *Daubert* standards, the Fifth Circuit, sitting en banc, upheld the trial court's exclusion of a physician-expert's opinion on the cause of the plaintiff's reactive airway disease. The witness had offered the opinion, without citing published research indicating that fumes from toluene and a mixture of other chemicals from a leaking drum could cause reactive airway disease. The Fifth Circuit held that the trial court had not abused its discretion in its application of the *Daubert* factors, noting that expert testimony must be based on at least "some objective, independent validation of the expert's methodology. The expert's assurances that he has utilized generally accepted scientific methodology [are] insufficient."¹⁵

chemical emissions identified by the defendant and stated that they had no opinion on whether plaintiff's complaints were related to air contamination from defendant's plant).

11. 509 U.S. 579 (1993).

12. 119 S. Ct. 1167 (1999). *Kumho* concerned a tire-failure expert who gave an opinion on the cause of a tire failure based on his examination of the tire and experience in examining tires. *Id.* at 1176–78. Similarly, medical testimony will almost always rely in part on clinical examination, though often in conjunction with other sources of information.

13. See Margaret A. Berger, The Supreme Court's Trilogy on the Admissibility of Expert Testimony § IV.C.2.b, in this manual.

14. 151 F.3d 269 (5th Cir. 1998) (en banc), *cert. denied*, 119 S. Ct. 1454 (1999). In a panel decision, the U.S. Court of Appeals for the Fifth Circuit had held that medical testimony in a toxic injury case was not subject to the factors *Daubert* suggests for scientific knowledge. *Moore v. Ashland Chem., Inc.*, 126 F.3d 679 (5th Cir. 1997). The court reconsidered that decision en banc, affirming the trial court's exclusion of the witness based on *Daubert*. 151 F.3d at 277–79. The en banc decision concluded that the trial court did not abuse its discretion, applying *General Electric Co. v. Joiner*, 522 U.S. 136 (1997). *Id.*

15. 151 F.3d at 276. See also *Black v. Food Lion, Inc.*, 171 F.3d 308 (5th Cir. 1999) (trial court should not have admitted a physician's testimony that trauma from a slip and fall had caused the plaintiff's fibromyalgia).

In contrast, the Third Circuit's decision in *Heller v. Shaw Industries, Inc.*,¹⁶ also a case decided before *Kumho* that applied *Daubert* standards, illustrates a much different approach. In *Heller*, as in *Moore*, the plaintiff complained of respiratory symptoms, which in this case coincided with exposure to a new carpet in her home. As in *Moore*, the trial court excluded the plaintiff's expert testimony because of the absence of published studies linking fumes from the carpet to allergic reactions. The Third Circuit stated that the trial court erred in so holding, noting the witness's reliance on "differential diagnosis."¹⁷ The court nonetheless upheld the exclusion of the witness's testimony on other grounds.

These two cases illustrate the range of approaches taken by courts in considering testimony on causation, including issues related to testimony on "differential diagnosis" or "differential etiology" (as witnesses and courts use these terms), the necessity of research literature to support opinions on causation, and the importance of temporal relationships. While these issues may be intertwined, they represent different facets of the courts' approaches.¹⁸

B. Medical versus Legal Terminology

Perhaps because medical testimony is so common and yet not entirely accessible to the lay public, courts have come to use certain medical terms, such as *differential diagnosis* and *differential etiology* in ways that differ from their common usage in the medical profession. For example, although environmental and occupational health physicians may use the term "differential diagnosis" to include the process of determining whether an environmental or occupational exposure caused the patient's disease,¹⁹ most physicians use the term to describe the process of determining which of several *diseases* is causing a patient's *symptoms*.

Expert witnesses and courts, however, frequently use the term "differential

16. 167 F.3d 146 (3d Cir. 1999).

17. *Id.* at 153–57. In this reference guide, the use of quotation marks around the terms *differential diagnosis* and *differential etiology* indicates the witness's or court's use of the terminology, which may differ from usage in the medical profession and from use elsewhere in this manual. See *infra* § I.B.

18. The appellate standard of review is also a critical factor in the analysis of the cases. The Supreme Court has twice instructed that a deferential abuse-of-discretion standard be applied to trial courts' admissibility decisions under Rule 702 of the Federal Rules of Evidence, including both rulings as to admissibility and the manner in which the trial court evaluates the proffered testimony. In *General Electric Co. v. Joiner*, 522 U.S. 136, 143 (1997), the Supreme Court held that an abuse-of-discretion standard applies to decisions on admissibility of expert testimony under *Daubert*. The Court reiterated that holding in *Kumho Tire Co. v. Carmichael*, 119 S. Ct. 1167, 1176 (1999), holding that abuse-of-discretion review applies to *how* the trial court assesses reliability.

19. The demonstration of causation has been described as a part of the process of diagnosing an environmental disease. See Mark R. Cullen et al., *Clinical Approach and Establishing a Diagnosis of an Environmental Medical Disorder*, in *Environmental Medicine* 217, 220 (Stuart M. Brooks et al. eds., 1995) [hereinafter *Environmental Medicine*]. The typical process of differential diagnosis is described more fully in section IV.B.

diagnosis” to describe the process by which causes of the patient’s condition are identified, particularly causes external to the patient.²⁰ Additionally, courts sometimes characterize causal reasoning as “differential etiology,” a term not used in medical practice, but one that more closely suggests the determination of cause.²¹ For the sake of clarity and consistency, this reference guide uses the term “differential diagnosis” in its traditional medical sense, that is, referring to the diagnosis of disease, and refers to the process of identifying external causes of diseases and conditions as “determining cause,” “determining external cause,” or some similar phrase, as the circumstances warrant.

To add a further level of complexity, courts also use the terms *general causation* and *specific causation*. General causation is established by demonstrating, often through a review of scientific and medical literature, that exposure to a substance can cause a particular disease (e.g., that smoking cigarettes can cause lung cancer). Specific, or individual, causation, however, is established by demonstrating that a given exposure is the cause of an individual’s disease (e.g., that a specific plaintiff’s lung cancer was caused by his smoking).²² Physicians may offer expert opinion on both specific and general causation,²³ although perhaps more commonly on specific causation as it relates to a patient’s medical condi-

20. See, e.g., *Kannankeril v. Terminix Int’l, Inc.*, 128 F.3d 802, 807 (3d Cir. 1997) (court recognized differential diagnosis “as a technique that involves assessing causation with respect to a particular individual” (citing *In re Paoli R.R. Yard PCB Litig.*, 35 F.3d 717, 758 (3d Cir. 1994), *cert. denied*, 513 U.S. 1190 (1995))); *National Bank of Commerce v. Associated Milk Producers, Inc.*, 22 F. Supp. 2d 942, 963 (E.D. Ark. 1998) (plaintiff could not show, under differential diagnosis approach, that contaminated milk caused his cancer), *aff’d*, 191 F.3d 858 (8th Cir. 1999); *Mancuso v. Consolidated Edison Co.*, 967 F. Supp. 1437, 1453 (S.D.N.Y. 1997) (proffered expert failed to conduct a differential diagnosis to exclude exposure to substances other than PCBs as the cause of plaintiffs’ ailments).

21. See, e.g., *Westberry v. Gummi*, 178 F.3d 257, 262 (4th Cir. 1999) (differential etiology analysis of talc as the cause of sinus problems); *Synder v. Upjohn Co.*, 172 F.3d 58 (9th Cir. 1999) (unpublished table decision) (text at No. 97-55912, 1999 WL 77975 (9th Cir. Feb. 12, 1999)) (differential etiology analysis of Halcion as the cause of criminal behavior).

22. The issues of general causation and specific causation are addressed in detail in Michael D. Green et al., *Reference Guide on Epidemiology* §§ V, VII, and Bernard D. Goldstein & Mary Sue Henifin, *Reference Guide on Toxicology* §§ III–IV, in this manual. The distinction between general causation and specific causation is discussed in *Zwillinger v. Garfield Slope Housing Corp.*, No. CV 94-4009, 1998 WL 623589, at *19–*20 (E.D.N.Y. Aug. 17, 1998) (plaintiff’s expert did not offer general causation evidence that outgassing from carpet could cause ailments suffered by plaintiff); *National Bank of Commerce v. Associated Milk Producers, Inc.*, 22 F. Supp. 2d 942, 963 (E.D. Ark. 1998) (although differential diagnosis “is undoubtedly important to the question of ‘specific causation,’” plaintiff must provide expert opinion on the issue of “general causation” based on a scientifically valid methodology (quoting *Cavallo v. Star Enter.*, 892 F. Supp. 756, 771 (E.D. Va. 1995), *aff’d in part, rev’d in part*, 100 F.3d 1150 (4th Cir. 1996), *cert. denied*, 522 U.S. 1044 (1998))), *aff’d*, 191 F.3d 858 (8th Cir. 1999).

23. See *In re Joint E. & S. Dist. Asbestos Litig.*, 964 F.2d 92, 96 (2d Cir. 1992); *Landrigan v. Celotex Corp.*, 605 A.2d 1079, 1086 (N.J. 1992) (permitting clinician to testify to specific causation based on epidemiology). *But see* *Sutera v. Perrier Group of Am., Inc.*, 986 F. Supp. 655, 662 (D. Mass. 1997) (physician not qualified to testify on epidemiology). See Michael D. Green et al., *Reference Guide on Epidemiology*, § VII, in this manual.

tion. When physicians offer expert opinion on general causation, it is frequently incorporated into proffered testimony on specific causation.

C. Relationship of Medical Testimony to Legal Rules

In litigation, the form and content of medical testimony is shaped by a number of factors, first and foremost of which is the legal issue on which it is offered. In terms of content, in a traditional personal injury claim, the physician may be asked to opine on the actual cause of the patient's illness or injury. Newer theories of tort, however, such as claims for fear of future injury (e.g., "cancer-phobia"),²⁴ increased risk of injury,²⁵ or medical monitoring,²⁶ require testimony on the patient's risk of future disease, rather than the actual cause.²⁷

The form of testimony, whatever the issue, tends to be shaped by requirements of the applicable legal rules. For example, courts and lawyers will be familiar with various formulations of the causation issue, including the "but for" and "substantial factor" tests. A physician testifying on causation issues will be asked to opine in the form dictated by the legal rule.

Legal rules on the sufficiency of proof will also shape the physician's testimony. In a personal injury case, physicians are often asked to testify on one or more of the ultimate issues in the case, such as causation. Thus, their testimony will be shaped by the applicable substantive rule on the burden of proof. For example, a physician may testify that a plaintiff's disease is "more likely than not"²⁸ due to a chemical exposure or that causation exists to a "reasonable medical certainty."²⁹ This reference guide, however, consistent with the purpose of this manual, focuses on the methods and reasoning governing physicians' decisions and opinions, not the differing legal rules and theories on which medical

24. See *Sterling v. Velsicol Chem. Corp.*, 855 F.2d 1188 (6th Cir. 1988); see generally Glen Donath, Comment, *Curing Cancerphobia Phobia: Reasonableness Redefined*, 62 U. Chi. L. Rev. 1113 (1995).

25. See *Gideon v. Johns-Manville Sales Corp.*, 761 F.2d 1129, 1137-38 (5th Cir. 1985) (recognizing a claim for increased risk of contracting cancer where the likelihood is a "reasonable medical probability" or "more likely to occur than not").

26. See *In re Paoli R.R. Yard PCB Litig.*, 916 F.2d 829 (3d Cir. 1990), cert. denied, 499 U.S. 961 (1991). But see *Metro-North Commuter R.R. v. Buckley*, 521 U.S. 424 (1997) (rejecting medical monitoring claim under the Federal Employers Liability Act). *Metro-North* also rejected a claim for negligent infliction of emotional distress based on fear of asbestos-related cancer. *Id.* at 437.

27. See *National Bank of Commerce v. Associated Milk Producers, Inc.*, 22 F. Supp. 2d 942 (E.D. Ark. 1998) (fear of future injury may be an element of damages, requiring expert opinion governed by *Daubert* standards), *aff'd*, 191 F.3d 858 (8th Cir. 1999).

28. See, e.g., *Cavallo v. Star Enter.*, 892 F. Supp. 756, 771 (E.D. Va. 1995), *aff'd in part, rev'd in part*, 100 F.3d 1150 (4th Cir. 1996), cert. denied, 522 U.S. 1044 (1998).

29. See, e.g., *Black v. Food Lion, Inc.*, 171 F.3d 308, 310 (5th Cir. 1999) (plaintiff's burden was to prove that her fall caused fibromyalgia "to a reasonable degree of medical certainty, based on a reasonable medical probability and scientifically reliable evidence"). See generally Jeff L. Lewin, *The Genesis and Evolution of Legal Uncertainty About "Reasonable Medical Certainty,"* 57 Md. L. Rev. 380 (1998).

testimony is offered, or the standards courts have applied in reviewing medical testimony.³⁰

This reference guide also does not address admissibility of testimony on the standard of care in medical malpractice cases. There are several reasons for this exclusion. First, medical malpractice cases are usually (though not exclusively) litigated in state courts rather than federal courts. Second, in most jurisdictions, the standard of care for physicians (like that for other professionals) is the customary level of care provided by competent physicians in the same field.³¹ Thus, testimony on the standard of care usually concerns what other physicians do in similar situations, rather than whether the defendant-physician's diagnosis and treatment are based on good medical science (although customary physician practice and good medical science will generally coincide). As a result, the admissibility of expert opinion on the standard of care is decided according to whether the witness is qualified to opine on the same field as the malpractice defendant.³²

Within the limitations described above, the next four sections of this reference guide explain medical practice, with an emphasis on how physicians apply medical and scientific knowledge, clinical experience, and patient history and examination to the process of diagnosis of disease and selection of appropriate treatment.

30. It is worth reminding readers that this guide is not intended to instruct judges concerning what medical testimony should be admissible as evidence. This chapter and the other reference guides attempt to contribute to the development of the law by clarifying scientific and professional practice in an area, thereby informing the development of consistent legal doctrines as courts consider individual cases. See the preface to this manual. This constraint, set by the Board of the Federal Judicial Center, is especially notable in this chapter. The lack of commentary on various standards should not be misunderstood as indicating that the authors have not given considerable thought to the manner in which such conflicts should be resolved. See generally Joan E. Bertin & Mary S. Henifin, *Science, Law, and the Search for the Truth in the Courtroom*, 22 J.L. Med. & Ethics 6 (1994); Susan R. Poulter, *Science and Toxic Torts: Is There a Rational Solution to the Problem of Causation?*, 7 High Tech. L.J. 189 (1992); Susan R. Poulter, *Medical and Scientific Evidence of Causation: Guidelines for Evaluating Medical Opinion Evidence*, in *Expert Witnessing: Explaining and Understanding Science* 186 (Carl Meyer ed., 1998). A summary of different approaches in applying evidentiary rules to medical testimony is offered in Margaret A. Berger, *The Supreme Court's Trilogy on the Admissibility of Expert Testimony*, § IV.C.2.b, in this manual. Moreover, proposed changes to Rule 702 by the Judicial Conference Advisory Committee on Evidence Rules, if enacted, may also affect the legal analysis of medical testimony.

31. 4 Lane Medical Litigation Guide §§ 40.21–.28, at 73–101 (Fred Lane & David A. Birnbaum eds., 1993 & Supp. 1996).

32. 1 *id.* § 4.15, at 18–20 (1994 & Supp. 1996). In some jurisdictions, the witness must be qualified to testify about the standard of care in a similar or even the same locality. 4 *id.* § 40.23, at 86–92 (1993 & Supp. 1996).

II. The Medical Doctor As an Expert

A. *What Is a Physician?*

In the United States, a physician is someone who has met the rigorous requirements of a four-year program and graduated from a credentialed medical or osteopathic school. However, as explained below, this training is not sufficient to qualify a physician to practice medicine.³³

The courses in medical school are generally similar from school to school, and they focus on basic medical sciences (e.g., microbiology, pharmacology, and pathology) as well as clinical training in medical diagnosis and treatment (e.g., internal medicine, cardiology, pulmonology, surgery, psychiatry, dermatology). All medical curricula include some basic training in epidemiology and biostatistics. There is relatively little structured study of public health, occupational medicine, and toxicology in a traditional curriculum, although a number of medical schools offer joint degree programs leading to a Master of Public Health degree (M.P.H.), with enhanced training in epidemiology, toxicology, and other aspects of public health. Furthermore, it is not uncommon for physicians to undertake further study and become proficient in epidemiological research in their particular fields. Most physicians have substantial training and experience in pharmacology, a subject closely related to toxicology that concerns the effects of therapeutic drugs.³⁴

In most states, physicians are required to complete a minimum of one additional year of hospital-based “residency” training, the first year of which is called an “internship,” in an approved program before they can be licensed to practice medicine. After completing the internship year, a physician may apply for state licensure to practice medicine. However, specialization requires further training in an approved residency program beyond the internship year. For example, surgery requires at least four additional years; family or internal medicine, pediatrics, or neurology requires two additional years. A physician may pursue subspecialty training, which usually requires a further one- to three-year “fellowship” focusing on a particular organ or system (e.g., pulmonology, cardiology, gastroenterology, rheumatology, endocrinology, hematology) or type of disease (e.g., infectious disease, oncology, or neurological movement disorders or electrophysiology).³⁵

33. See World Health Org., *World Directory of Medical Schools* 274–75 (6th ed. 1988 & Supp. 1997).

34. See, e.g., Association of Am. Med. Colleges, *Curriculum Directory* 1998–99, at 104–05 (27th ed. 1998) (listing required courses for Johns Hopkins University School of Medicine).

35. See World Health Org., *supra* note 33, at 274–75.

After a physician has completed a residency or fellowship in a specialty, he or she is eligible to take an examination given by that medical specialty's "board." There are twenty-three specialty and subspecialty boards administered by the American Board of Medical Specialists (ABMS), as well as a number of other boards not under ABMS with more idiosyncratic criteria for certification. Passing such an exam makes the physician "board certified" in the field or subspecialty—a marker of substantial proficiency within the particular area of medicine and a credential often required by hospitals for appointment to their medical staff.³⁶ Other indicia of expertise include academic appointments, published articles in peer-reviewed journals, grant awards, and appointment to peer review panels.³⁷

After the conclusion of formal medical education, including internship and residency, physicians continue to acquire medical knowledge through clinical experience, hospital-based lectures and training programs, review of medical literature, and continuing medical education courses that provide information in various specialties. A number of states have moved toward requiring continuing medical education for license renewal.³⁸ An increasing number of medical specialties require passage of the board examination at regularly scheduled intervals to maintain board certification.

To practice at a hospital, a physician must pass review by a "credentialing committee" that examines the credentials of the physician, as well as legal and state board records concerning the physician. A physician who clears the credentialing committee may become a member of the hospital's medical staff, otherwise known as an "attending physician," and may admit patients to the hospital for treatment. A hospital may revoke staff and admitting privileges for

36. Although it may be helpful in establishing the witness's credentials for opinion testimony, courts usually do not apply a strict requirement of specialization or board certification for most purposes. See, e.g., *Holbrook v. Lykes Bros. S.S. Co.*, 80 F.3d 777, 782–83 (3d Cir. 1996) (physician board certified in pulmonary medicine not required to be a specialist in oncology and radiation to testify on causation of mesothelioma). In contrast, admissibility of testimony on the medical standard of care in medical malpractice cases is typically controlled through screening of the witness's qualifications. See, e.g., *Marquardt v. Joseph*, 173 F.3d 855 (6th Cir. 1999) (unpublished table decision) (text at No. 98–5163, 1999 WL 196569 (6th Cir. Mar. 30, 1999) (dentist who was not an oral surgeon was not qualified to testify on the standard of care for oral surgery)); *Carroll v. Morgan*, 17 F.3d 787, 790 (5th Cir. 1994) (cardiologist with many years of experience need not be a specialist in pathology to testify on the relationship between heart problems and death).

37. The American Medical Association (AMA) has taken an interest in the quality of medical expert testimony. After reviewing cases involving testimony by physicians who had falsified their credentials, the AMA issued a 1998 report to its Board of Trustees recommending that the AMA encourage state licensing boards to develop disciplinary measures for physicians who provide fraudulent testimony. The House of Delegates adopted an amended version of the report. See Michael Higgins, *Docking Doctors? AMA Eyes Discipline for Physicians Giving 'False' Testimony*, A.B.A. J., Sept. 1998, at 20.

38. Jeffrey K. Stross & Thomas J. DeKornfeld, *A Formal Audit of Continuing Medical Education Activity for License Renewal*, 264 JAMA 2421 (1990) (audit of continuing medical education activities of

cause.³⁹ Some hospital physicians are also members of the teaching staff, charged with the training of interns and residents in their medical specialties. Most, but not all, teaching staff have joint academic appointments at a medical school.

B. Physicians' Roles in Patient Care

After completion of training, a physician may be involved in various aspects of medicine. While the public tends to think of a physician as directly involved in patient care, a practicing physician may also serve as a "consulting physician," conduct medical research, or have an academic appointment.⁴⁰ Although the lines between these different roles often blur, understanding the range of activities undertaken by physicians is helpful.

A treating physician's primary role is the examination, diagnosis, and treatment of patients.⁴¹ The physician is expected to do one or more of the following: diagnose the patient's conditions, recommend or provide appropriate treatments, and monitor the patient's progress. The treating physician may also, as appropriate, counsel patients on the management of diseases, as well as on dietary habits, genetic and familial risks and other aspects of a patient's life relevant to preventing disease, maintaining health, or managing disease or injury. A treating physician may be a specialist or nonspecialist. Some members of a treating team of physicians, such as radiologists or pathologists, perform primarily diagnostic roles and rarely prescribe treatment.

A consulting physician is someone who is asked for recommendations for diagnosis and treatment or a "second opinion," based on his or her more specialized knowledge and experience. Examples include a cardiologist brought in to assist the primary physician with the care of someone after a heart attack and a pulmonary specialist brought in to assist with the management of a patient with asthma. The consulting physician may rely, in whole or in part, on information developed by other medical practitioners contained in the patient's medical records, such as medical history, laboratory tests, and x-rays. More often, the consulting physician will also conduct an examination of the patient and under-

physicians licensed in Michigan to assess compliance with a law mandating participation in 150 hours of continuing medical education every three years).

39. *Chouteau v. Enid Mem'l Hosp.*, 992 F.2d 1106, 1109 & n.2 (10th Cir. 1993) (upholding the district court's grant of summary judgment, finding that sufficient justification existed for the defendant hospital to lawfully terminate the plaintiff's staff privileges).

40. See Alvan R. Feinstein, *Clinical Judgment* 21 (photo. reprint 1985) (1967).

41. Treating physicians are generally permitted to testify, although contentions are sometimes made that their testimony should be limited. In *Holbrook v. Lykes Bros. Steamship Co.*, 80 F.3d 777 (3d Cir. 1995), the trial court had excluded the treating physician's testimony on his diagnosis of mesothelioma and a pathology report because the physician was not a pathologist or oncologist. The Third Circuit reversed the decision, noting that treating physicians' testimony is often given greater weight than testimony from physicians who have not examined the patient. *Id.* at 782-83.

take additional tests and investigations. While consulting physicians are often an integral part of the team of treating physicians, in some instances they may not be involved in treatment, instead providing opinions for employers, insurers, litigants, or courts.

C. Medical Research and Academic Appointments

In addition to traditional patient care and consultation as to diagnosis and treatment, physicians may be involved in medical research in a variety of areas (e.g., epidemiology, pharmacology, and toxicology) as their primary activity, or in conjunction with patient-oriented medical practice. For example, physicians may be involved in clinical trials to evaluate new drugs or other therapies. They also may participate in studies on the causes of disease. The physician may be the principal investigator, who is primarily responsible for such studies, or may participate as a coinvestigator or collaborator, or simply by referring patients to the studies. Many physicians involved in medical research also have a teaching position at a medical school or a large teaching hospital.

D. Physicians As Expert Witnesses

In contrast to the traditional medical roles they fill as outlined above, physicians frequently act as witnesses in court, either for the parties or, on occasion, as court-appointed experts. Physician-witnesses may testify based on their activities as treating or consulting physicians or more generally about medical and scientific knowledge and its application to the issues in a case. In the former role, they may be characterized as “fact” witnesses, but they will also be applying medical expertise to a greater or lesser degree in assessing the significance of the patient’s signs and symptoms and medical history, making a diagnosis, opining on proper treatment and prognosis, and the like. In some medical fields, such as clinical toxicology or occupational medicine, this dual role is quite common. In other instances, the physician is applying his or her expertise solely to offer an expert opinion, relying on factual clinical information developed by treating physicians or from hospital records or other sources.⁴²

A physician may be asked to testify about the physical condition of a plaintiff, diagnosis, treatment, causes of the plaintiff’s condition, or prognosis. A physician may also be asked to interpret epidemiological or industrial hygiene data if they are within his or her scope of expertise. Such testimony may be important

42. Howard Hu & Frank E. Speizer, *Influence of Environmental and Occupational Hazards on Disease*, in 1 Harrison’s Principles of Internal Medicine 18, 19 (Anthony S. Fauci et al. eds., 14th ed. 1998) [hereinafter *Principles of Internal Medicine*].

both in a factual sense—what happened and when—and as a basis for expert opinion on such issues as the following:

1. Is the diagnosis correct? (assessing what injury the plaintiff suffered);
2. Were the appropriate treatments prescribed? (assessing the issues of standard of care in a medical malpractice case or damages in a tort case);
3. What is the prognosis or the likely course of the plaintiff's condition? (assessing future damages);
4. Was the patient exposed to the substance in question? (assessing exposure through patient symptoms and reports, such as eye burning, the detection of an odor, or a headache, which provide indications as to the concentration of an irritant or other agent);
5. Is there an increased risk of future disease? (assessing damages by predicting future consequences of an existing condition; assessing a claim for increased risk of future disease; assessing the reasonableness of a claim for fear of disease (e.g., cancerphobia); or assessing the propriety of medical surveillance in a medical monitoring claim); and
6. What caused the plaintiff's medical condition? (assessing general and specific causation).

As set forth later in this reference guide,⁴³ physicians do not always use the same approach in evaluating these issues as the legal system does. For example, in tort cases, liability will often turn on the identification of one or more causes of the plaintiff's condition. A physician, independent of legal issues, typically uses the term *causation* or *etiology* to refer to the various levels of underlying abnormality that have substantially led to the next higher level of abnormality, disease, or diagnosis. This "chain," or web, of causation is considered the "pathogenesis" or pathophysiology of a disease. For instance, a heart attack may be due to a sudden blockage of a coronary artery, which was facilitated by a preexisting cholesterol plaque in the artery, which in turn is due to the patient's high level of blood cholesterol, which is due to genetics, diet, a sedentary lifestyle, and smoking, which contributes at many levels.⁴⁴ Most physicians are familiar with the general importance, if not specific degrees of risk, of the listed internal biochemical and mechanical factors in a heart attack, and with many other areas in the web of causation, such as the common external factors listed above.⁴⁵

43. See *infra* § IV and accompanying footnotes.

44. Elliot M. Antman & Eugene Braunwald, *Acute Myocardial Infraction*, in 1 Principles of Internal Medicine, *supra* note 42, at 1352, 1352–53. In this guide, the term *internal* is used to refer to causal factors and conditions internal to the patient's body, such as genetic predisposition to coronary artery disease, to distinguish them from causal factors that are *external* to the body, such as smoking and diet.

45. For a general discussion of the process used to infer internal and external causation, see Feinstein, *supra* note 40, at 80–83. See, e.g., *Carroll v. Morgan*, 17 F.3d 787, 791 (5th Cir. 1994) (discussing multiple causes of plaintiff's coronary disease).

While physicians dealing with diagnosis and treatment tend to think in terms of both internal and external causation, courts are usually asked to determine the role of causes that are external to the individual. Generally, physicians focus on causal elements that can be addressed through medical treatment or through changes in lifestyle or diet; courts focus primarily on causal elements for which a litigant or other party might be held responsible. For example, a workers' compensation case might concern the role of physiological stress at work in causing underlying heart disease, or the role of carbon monoxide in triggering a specific heart attack.⁴⁶ Identification of those kinds of causes depends on information concerning quantification of risks in the workplace environment, as well as on the medical literature on causation, including the psychological, toxicological, and epidemiological literature.⁴⁷ To determine general causation, the expert must review the pertinent literature, as familiarity with this literature is key to expert opinion. For example, since many cardiologists advise patients on returning to work after a heart attack, they will often be familiar with the literature on work-based risks and cardiovascular disease, whereas most other physicians, who deal with this question less frequently, would need to devote some time to study before evaluating such a special consideration.

III. Information Utilized by Physicians

Physicians rely on the following diverse sources of information in arriving at a diagnosis, determining a course of treatment, and exploring causation: the patient history (information derived directly from the patient), patient records, physical examination, and diagnostic tests.⁴⁸

A. Patient History (from the Patient)

The patient history is one of the primary and most useful tools in the practice of clinical medicine. It is usually divided into present illness (including both subjective reports and medical documentation) and past medical problems, with or without medical documentation.⁴⁹

As obtained by the examining physician, the patient history is extremely important in evaluating the patient's condition, determining what medical tests may be warranted, arriving at a diagnosis, and recommending an appropriate

46. See, e.g., *Fiore v. Consolidated Freightways*, 659 A.2d 436 (N.J. 1995) (truck driver's workers' compensation case claiming that his heart disease was caused by occupational exposure to carbon monoxide fumes remanded so that parties could provide more reliable exposure evidence).

47. See Cullen et al., *supra* note 19, at 220–21.

48. See Jerome P. Kassirer & Richard I. Kopelman, *Learning Clinical Reasoning* 4 (1991).

49. Barbara Bates et al., *A Guide to Physical Examination and History Taking* 2–3 (6th ed. 1995).

course of treatment. Even in this era of sophisticated medical testing protocols, it is estimated that 70% of significant patient problems can be identified, although not necessarily confirmed, by a thorough patient history.⁵⁰

A thorough patient history includes not only present illness and past medical problems, but also aspects of medical, occupational, personal, and familial background that are relevant to the present problem. Moreover, patient histories may identify common patterns of illness among individuals with a common lifestyle or exposure element, such as reproductive problems in individuals occupationally exposed to lead. Although patient histories are important in determining a diagnosis, and useful in epidemiological studies of both acute and chronic diseases, there is no validated and widely used patient history questionnaire with which to begin the diagnostic process,⁵¹ perhaps because the history-taking process is so iterative and intertwined with hypothesis testing.

Despite the absence of a standard patient history questionnaire, there is general agreement that a useful adult patient history includes the following information:

1. identification (e.g., name, sex, age);
2. chief complaint and history of the present illness;
3. medical history (e.g., injuries, medical conditions and diseases, surgical procedures);
4. lifestyle characteristics (e.g., use of nicotine, alcohol, and other drugs; exposures in the home);
5. familial health (e.g., medical conditions and diseases of relatives); and
6. occupational history (e.g., present and previous employment, exposures).⁵²

While more recent events or those that more directly appear pertinent to the particular presenting symptoms of a patient will usually be given the most attention, historic events or familial history may provide insight into diagnosis and prognosis.⁵³ This is particularly true when the physician is considering exposure-disease relationships with a long latency, such as in asbestos-related disease or inherited predispositions for malignancy.⁵⁴

1. Symptomatology

Symptoms are by definition subjective, since they are self-reported by the patient in his or her own words. Because symptoms that preoccupy the patient are not always the most relevant to diagnosis, the physician will often need to ask

50. See Mark H. Swartz, *Textbook of Physical Diagnosis: History and Examination* 667 (3d ed. 1998).

51. Office of Tech. Assessment, U.S. Congress, *Reproductive Health Hazards in the Workplace* app. B at 365 (1985).

52. See, e.g., Bates et al., *supra* note 49, at 3-7, 16-17.

53. See, e.g., *id.* at 637-39.

54. See Thomas E. Andreoli et al., *Cecil Essentials of Medicine* 152 (3d ed. 1993).

the patient about symptoms that are particularly useful for diagnosis, but not of particular concern to the patient. Generally, patients will be asked to characterize symptoms by their location, intensity, frequency, exacerbating factors, ameliorating factors, and novelty.⁵⁵

As a report of the patient's own experience, symptoms are uniquely valuable, but they are also subject to various sources of bias and error, both intentional and unintentional. A competent diagnostician can take sources of error into account, but for some symptoms, such as severity of pain, or when the first severe attack of shortness of breath occurred, it is usually not possible to objectively verify the patient's reports. The physician's skill, knowledge, and experience with the particular area of concern is critical in obtaining an accurate and meaningful history.⁵⁶ Physicians are accustomed to reaching a subjective conclusion regarding the quality and reliability of the history they obtain from the patient.

2. Environmental and Occupational History

Consideration of occupational and environmental causation in diagnosis has long been recommended to physicians, but more specific attention to the environmental and occupational history as part of the medical workup has recently been emphasized, with the degree of detail depending on the clinical situation.⁵⁷

If the medical workup indicates a potential occupational or environmental disease, the physician should explore the patient's potential exposures in more detail.⁵⁸ Although the physician often will not have measures of environmental exposure, information about the level of exposure can be inferred in certain instances from the description of the workplace and work processes; the duration of exposure; correlates, such as eye irritation, headache, or odor; the size of a room or other enclosure; the presence of windows or other ventilation; and other activities occurring nearby.⁵⁹

55. See, e.g., Bates et al., *supra* note 49, at 635, 645–47.

56. See Anthony S. Fauci et al., *The Practice of Medicine*, in 1 Principles of Internal Medicine, *supra* note 42, at 1, 2; Lee Goldman, *Quantitative Aspects of Clinical Reasoning*, in 1 Principles of Internal Medicine, *supra* note 42, at 9, 9.

57. See Hu & Speizer, *supra* note 42, at 19; Environmental Medicine: Integrating a Missing Element into Medical Education 5–11 (Andrew M. Pope & David P. Rall eds., 1995).

58. Establishing exposure is usually deemed necessary to a plaintiff's toxic injury claim, and the existence or degree of exposure to the agent is often at issue. See, e.g., *In re Paoli R.R. Yard PCB Litig.*, 916 F.2d 829 (3d Cir. 1990) (environmental exposure to polychlorinated biphenyls (PCBs) contested), *cert. denied*, 499 U.S. 961 (1991).

59. See Hu & Speizer, *supra* note 42, at 19; Frank E. Speizer, *Environmental Lung Diseases*, in 2 Principles of Internal Medicine, *supra* note 42, at 1429, 1429–30; Peter Casten, Jr., & Katherine Lofffield, *The Eyes and Vision*, in Environmental Medicine, *supra* note 19, at 240, 242. Exposure to chemical agents typically found in certain work environments can sometimes be inferred based on industrial hygiene studies of particular occupations. For example, employment as an asbestos insulator has been associated with significant levels of asbestos exposure.

Information about exposure may also be available from workplace industrial hygiene records or a police report. Other sources of information may include governmental agency or private consultant records and insurance inspections. However, physicians usually have to evaluate environmental or occupational diseases in the absence of quantitative exposure levels. Even in situations in which there are measurements of personal breathing-zone exposures, such data may not take into account various other factors, such as the level of a patient's exertion, which may change the actual dose to make it greater or lower than theoretical calculations; the performance of ventilation equipment; or the fit of a respirator.⁶⁰

3. Other Risk Factors

In addition to information about environmental and occupational exposures, a patient's history should include information about other known risk factors, such as the patient's family history, smoking history, amount of exercise, alcohol use, use of medications or illicit drugs, and exposures to chemicals in the home or from hobbies.⁶¹

B. Past and Present Patient Records and Exposure-Related Records

Although time-consuming and bureaucratically cumbersome, an examination of patient records from former treating physicians, clinics, and hospitals can often be crucial for accurate diagnosis, for determination of the onset of an illness or symptom, and to provide information about external exposures. Patient records may reveal the course of an illness and the results of prior tests, and they can help gauge the reliability of patient-reported information. Unfortunately, because obtaining multiple patient medical records from various institutions in a timely manner is often difficult, much medical care is rendered in their absence. More complete records are often gathered once litigation has begun.

C. Physical Examination⁶²

The physical examination is a routine procedure for evaluating the patient and determining a diagnosis. The physical examination identifies approximately 20%

60. For the effect of exercise, see, e.g., Joseph D. Brain et al., *The Effects of Exercise on Inhalation of Particles and Gases, in Variations in Susceptibility to Inhaled Pollutants: Identification, Mechanisms, and Policy Implications* 204, 210 (Joseph D. Brain et al. eds., 1988); for other variables affecting an individual's exposure and response to inhaled gases or particles, see, e.g., Speizer, *supra* note 59, at 1430.

61. See Bates et al., *supra* note 49, at 16–19; Speizer, *supra* note 59, at 1429–30.

62. Courts sometimes attach importance to the physician-witness's examination of the patient. See, e.g., *In re Paoli R.R. Yard PCB Litig.*, 35 F.3d 717, 771 (3d Cir. 1994) (physician's testimony on causation admitted as to patients the witness examined), *cert. denied*, 513 U.S. 1190 (1995); *In re "Agent Orange" Prod. Liab. Litig.*, 611 F. Supp. 1223, 1235, 1243–47 (E.D.N.Y. 1985), *aff'd*, 818 F.2d 187

of significant medical problems.⁶³ The physical exam has standard components with which physicians, depending on their degree of specialization, may be more or less proficient. For example, while most physicians will hear a loud heart murmur or identify a severe tremor, subtle signs of heart disease or neurological disease may be missed by those without specialty training in cardiology⁶⁴ or neurology, respectively. Greater proficiency can be expected from a specialist, because doctors in specialized fields focus their examinations on the system in question, do more tests within an area, are more skilled in performing the exam, and are better able to distinguish between significant and insignificant deviations from normal.

The findings from the physical exam as well as radiographic imaging studies, noninvasive functional tests, and blood tests are referred to as “signs” of illness, as contrasted with symptoms, which are subjectively reported by the patient. Although signs are more objective than symptoms, they still depend on the physician’s skill and objectivity, degree of attention to detail, and level of concern. Physical signs assume enhanced significance when they demonstrate the presence of a functional or structural change already suggested by the patient history.⁶⁵

A thorough physical exam begins with the taking of vital signs (temperature, heart rate, respiratory rate, and blood pressure). Next is a description of the patient’s general appearance and whether the patient was able to cooperate with the exam. This is followed by examination of each region and organ system (skin, head, ears, eyes, nose, mouth and throat, neck, chest, lungs, heart and cardiovascular system, abdomen, genitourinary system, extremities and musculoskeletal system, and nervous system). Psychological assessments are sometimes then provided.⁶⁶ However, many specialists may perform only a portion of the exam; and, because of time constraints, many practitioners focus on only one aspect of a patient at a given time.⁶⁷

Physicians are taught to record their findings on a physical exam in a routinized but not necessarily standardized fashion. A thorough exam will include

(2d Cir. 1987), *cert. denied*, 487 U.S. 1234 (1988). Courts have also recognized that physicians may present testimony based on examinations and tests performed by others, as well as on medical records. *See, e.g.*, *Kannankeril v. Terminix Int’l, Inc.*, 128 F.3d 802, 809 (3d Cir. 1997); *Sementilli v. Trinidad Corp.*, 155 F.3d 1130 (9th Cir.) (per curiam) (physician could present testimony on plaintiff’s condition based on medical records and knowledge, experience, training, and education), *dissenting opinion amended*, 162 F.3d 1015 (9th Cir. 1998).

63. *See Swartz, supra* note 50, at 667.

64. *See, e.g., Feinstein, supra* note 40, at 2.

65. *See Fauci et al., supra* note 56, at 2.

66. *See Bates et al., supra* note 49, at 118–21.

67. *Id.* at 117.

“findings” as opposed to merely notes indicating that an observation was “within normal limits” or “negative.” However, the emphasis is on the accuracy of the observation, rather than the degree of detail that may be presented. How the findings of the physical exam fit into context with other data in the case is a key item in assessing the exam’s reliability.⁶⁸

As discussed above, specialists are generally better able than generalists to elicit patient history information, ascertain physical findings, and interpret lab results within their area of expertise. Findings that may have limited clinical meaning but may inform decisions regarding external causation in legal proceedings, such as the bilateral asymptomatic stable pleural thickening in someone with a history of asbestos exposure, are sometimes not mentioned by a treating physician, such as a radiologist. Thus, the absence of such findings from the treating physician’s records should not necessarily be taken as an indication of disagreement between the treating physician and the specialist.

D. Diagnostic Tests

For diagnosis of more serious conditions, especially cancer, physicians are taught always to seek a tissue biopsy.⁶⁹ This is often referred to as a gold standard, because it is regarded as highly accurate or at least the most definitive indicator of a particular condition. For other conditions, the definitive test may be a radiological test (e.g., a pulmonary angiogram for diagnosis of pulmonary embolism)⁷⁰ or a microbiological test (e.g., a sputum culture for diagnosis of tuberculosis).⁷¹

Sometimes physicians and patients will be satisfied with a diagnosis even though the gold standard test for that diagnosis was not performed. There may be too much risk associated with such a test (e.g., if it is invasive or involves intentional exposure to a possible allergen), its costs may outweigh the benefit of achieving a more definitive diagnosis, or it may be superfluous because other data are so consistent and convincing.⁷² As always, the various cost–benefit and risk–benefit equations are interpreted relative to the individual patient, physician, and medical circumstances, as well as institutional capabilities.

68. *Id.* at 649–52.

69. See, e.g., Dan L. Longo, *Approach to the Patient with Cancer*, in 1 *Principles of Internal Medicine*, *supra* note 42, at 493, 494.

70. See Steven E. Weinberger & Jeffrey M. Drazen, *Diagnostic Procedures in Respiratory Disease*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 1417, 1418.

71. See Matthew E. Levinson, *Pneumonia, Including Necrotizing Pulmonary Infections (Lung Abscess)*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 1437, 1440.

72. See Kassirer & Kopelman, *supra* note 48, at 217–22.

In modern medical practice, tests and procedures are critical to confirming most diagnoses. These include radiological examination, laboratory tests, physiological tests of lung or nerve function, pathological examination of tissue, and invasive diagnostic tests, such as cardiac catheterization. A physician's decision whether to order a diagnostic test for specified clinical indications should take into consideration expense, risk, accuracy, and predictive value. Tests are limited by their inherent sensitivity and specificity, the fallibility of the instrumentation, and the variation in skills of the individuals who perform or interpret the tests. Error rates for diagnostic tests, as discussed below,⁷³ in terms of sensitivity and specificity are generally available, but the all-important predictive values⁷⁴ vary with the particular disorder and with the population (i.e., demographics, background rate of disease) on whom the test is performed or the population from which a tested individual is derived. While pathological examination of tissue biopsies is considered the gold standard of diagnostic tests, even it has an error rate.⁷⁵

In general, laboratory tests do not have a paramount role in establishing the external etiology of many chronic and acute illnesses. Major exceptions to this are microbiological evaluations for causes of infectious diseases, and cases of toxic substance intoxication, such as lead poisoning or alcohol or drug poisoning.⁷⁶

Depending on the diagnosis being considered and whether the exposure truly leaves a reliable "signature" or "residue,"⁷⁷ a biopsy may or may not have great utility for exogenous causal diagnosis. Invasive tissue biopsies are not routinely performed for purposes of establishing causation because of the risk involved with the procedure to obtain the tissue. Sometimes such test results are incidentally available because they may have been used to establish the diagnosis, particularly in the case of lung disorders.

73. See *infra* note 105 and accompanying text.

74. See *infra* notes 107–108 and accompanying text.

75. See Fauci et al., *supra* note 56, at 3; Goldman, *supra* note 56, at 10; Kassirer & Kopelman, *supra* note 48, at 23.

76. See Christopher H. Linden & Frederick H. Lovejoy, Jr., *Poisoning and Drug Overdose*, in 2 Principles of Internal Medicine, *supra* note 42, at 2523, 2523–25.

77. Certain persistent toxic agents can sometimes be detected in laboratory tests. See, e.g., *Hose v. Chicago Northwestern Transp. Co.*, 70 F.3d 968 (8th Cir. 1995) (laboratory tests showed elevated manganese in plaintiff's body; MRI indicated manganese in brain). The interpretation of such tests has been at issue in a number of cases. See, e.g., *In re Paoli R.R. Yard PCB Litig.*, 35 F.3d 717 (3d Cir. 1994) (dispute over whether PCB levels in plaintiffs' adipose tissue exceeded background levels), *cert. denied*, 513 U.S. 1190 (1995); *Wright v. Willamette Indus., Inc.*, 91 F.3d 1105 (8th Cir. 1996) (presence of wood dust fibers at plaintiffs' residence and in tissue samples insufficient to establish exposure to formaldehyde at levels known to cause plaintiffs' symptoms).

1. Laboratory Tests

Laboratory tests are usually tests in which a specimen, usually blood or another body fluid, is submitted to a laboratory for a chemical or microbiological analysis. For many of the routine chemical assays for levels of proteins, fats, electrolytes, enzymes, or hormones in blood, there are established normal ranges for a given laboratory or test manufacturer, and for given subpopulations (e.g., men or women, children or adults). The results are interpreted as being either within or outside of normal limits. Not all deviation from normal limits is pathological, particularly if the individual is otherwise without complaint. For example, the results of liver function tests often fluctuate outside of the normal range in those without liver disease or hepatotoxin exposure. Based on standard statistical techniques for defining normal ranges, one in twenty test results can be expected to be abnormal (i.e., outside the normal range) in a healthy individual.⁷⁸

Common laboratory tests include x-rays, routine blood chemistries, and blood counts. More specialized tests include computerized axial tomography (CAT) scans, magnetic resonance imaging (MRIs), and angiograms.⁷⁹ All of these tests are used in one of three ways as part of the diagnostic process. The first and most common use is to clarify a disease process or pathology or pathophysiology.⁸⁰ A second and less common use of laboratory tests is for estimation of exposure to potentially toxic substances. These tests include measures of an agent in the body (e.g., blood lead levels) or in an excretory product (e.g., urine mercury). Understanding that such tests only determine exposure and not disease or health effect is critical.⁸¹ A third and fairly uncommon type of laboratory test is used to substantiate an exposure–effect relationship.⁸² Many, if not most, such tests are actually tests of allergic sensitization (e.g., to a metal or other potential cause of allergic asthma). The expert should be clear about what type of information is being inferred from a given test and about the basis in the literature for using the test for that purpose.⁸³

78. See Cullen et al., *supra* note 19, at 223–24. For an overview of available blood tests, fluid analysis studies, and urinalyses, see, e.g., Kathleen Deska Pagana & Timothy James Pagana, *Mosby's Manual of Diagnostic and Laboratory Tests* 7–9, 557, 859–73 (1998).

79. See Fauci et al., *supra* note 56, at 3; for uses of laboratory tests in environmental disease, see Cullen et al., *supra* note 19, at 222–23 and Arthur Frank, *The Environmental History*, in *Environmental Medicine*, *supra* note 19, at 232. See also *In re Paoli R.R. Yard PCB Litig.*, 916 F.2d 829 (3d Cir. 1990), *cert. denied*, 499 U.S. 961 (1991).

80. For a case involving the use of laboratory tests in diagnosis, see *Cella v. United States*, 998 F.2d 418 (7th Cir. 1993).

81. See, e.g., Linden & Lovejoy, *supra* note 76, at 2523.

82. See Cullen et al., *supra* note 19, at 223.

83. See *id.* at 228. For an example of laboratory tests used to rule out alternative diagnoses and causes, see *Hose v. Chicago Northwestern Transportation Co.*, 70 F.3d 968, 973, 975 (8th Cir. 1995) (supporting a diagnosis of manganese encephalopathy, medical witnesses cited a positron emission tomography (PET) scan to rule out alcoholism, stroke, and Alzheimer's disease, and an MRI to exclude copper, calcium, and other harmful exposures).

Physicians are taught to think about clinical testing in terms of the clinical significance (particularly, predictive value) of a given test in a given situation. Small or inconsistent changes in values do not necessarily indicate a clinically important effect and should be confirmed by repeat testing before being otherwise investigated. On the other hand, important effects may not drive an individual's values outside of the population reference range. For instance, someone previously at the upper limit of the normal range exposed to a chlorine leak might suffer a reduction in rate of airflow. Although the subsequent rate was within the normal range, it would not be normal in this individual.⁸⁴ Unfortunately, baseline data on an individual prior to exposure are usually not available. Thus, making inferences from other diagnostic and exposure information may be useful in understanding the impact of exposure on that individual.

2. Pathology Tests

Pathology tests are conducted by taking a sample of body tissue (obtained during surgery or a biopsy) and submitting it for microscopic evaluation by a specialist physician (pathologist). The pathologist makes a determination as to whether the tissue appears normal for the organ from which it was taken. If it does not appear normal, then a determination of the pattern of abnormality, such as inflammation, malignancy, or scarring, is sought.⁸⁵

Sometimes the etiology of the abnormality is apparent, as when special stains are used for determination of the presence of microorganisms that can cause a given infection. On the other hand, most cancers, whether of lung or breast or bone marrow, have no features that allow the histopathologist to discern a toxic, viral, or hereditary etiology. Clues from molecular biology analysis have been experimentally reported, but are not yet available clinically.⁸⁶

Pathology, typically felt to be the gold standard, often is found wanting when external etiology needs to be determined. Some conditions, such as neuropsychiatric diseases that may be related to metal or solvent exposure, do not have established pathological abnormalities.⁸⁷

3. Clinical Tests

Clinical tests are physiological determinations of organ function. Common examples are pulmonary (lung) function tests, which have well-established normal

84. Cullen et al., *supra* note 19, at 223.

85. For specific examples, see Ivan Damjanov, *Histopathology: A Color Atlas and Textbook* 23–24, 36, 58, 64 (1996).

86. See Bernard D. Goldstein & Mary Sue Henifin, *Reference Guide on Toxicology* § IV, in this manual.

87. See Howard Hu, *Heavy Metal Poisoning*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 2564, 2565–66.

ranges, but are quite dependent on patient effort; nerve and muscle function tests, which are largely effort-independent and have reasonably well-established reference ranges, but are sensitive to interlaboratory variation, and electrocardiograms (EKGs), which are interpreted with a combination of objective measures and more subjective recognition of patterns resulting from individual expertise.⁸⁸

All tests have strengths and limitations for their use in reaching a certain diagnosis or making a causal inference. The expert should be able to address strengths and weaknesses of various approaches based on the situation at hand. Why was one test chosen or preferable to another? If available, what is the sensitivity, specificity, and validity for the test in general, and what are its predictive values in the population (characterized by age group, gender, comorbid diseases, workplace exposures) from which the individual comes?⁸⁹

Mostly these predictive values will be available in the medical literature, but there are many disappointing gaps. Given inevitable inconsistencies in the patient's data, a qualified expert will usually be able to interpret and explain these inconsistencies in a satisfactory manner.

IV. Physician Decision Making

A. Introduction

For the treating physician, “[c]linical reasoning is the essential function of the physician; optimal patient care depends on keen diagnostic acumen and thoughtful analysis of the trade-offs between the benefits and risks of tests and treatments.”⁹⁰ Beyond assessing the presence or absence of disease, and defining appropriate treatment or prevention, the physician must be able to skillfully communicate information to the patient and other interested parties.⁹¹

Moreover, a physician may be asked to determine the causation of disease, in order, for example, to offer a patient advice on continuing activities that may cause, contribute to, or exacerbate or ameliorate the disease. The physician may also be asked to determine causality as an expert in a legal proceeding.⁹² In undertaking all of these activities, the physician is grounded in the art and science of clinical reasoning, which we describe below in general terms.

88. For specific tests of pulmonary, nerve and muscle function, and electrocardiography, respectively, see Pagana & Pagana, *supra* note 78, at 1016–21, 490–92, 486–89, 478–82.

89. See *infra* § IV and accompanying footnotes.

90. Kassirer & Kopelman, *supra* note 48, at 2.

91. See Cullen et al., *supra* note 19, at 217.

92. See Hu & Speizer, *supra* note 42, at 19, 20.

The physician is trained to recognize diseases as coherent deviations from normal structure or function that affect a certain part of the body or type of tissue. Physicians recognize the characteristic symptoms, signs, and laboratory manifestations of given diseases, although a relatively small number of discrete symptoms and signs are shared by a much larger number of coherent diseases. In fact, diseases result from one or a combination of only ten or so general pathophysiological processes (congenital, infectious, neoplastic, toxic, genetic, vascular, immunologic, inflammatory, endocrine, and traumatic). The goal of the physician is to distinguish which specific type of disorder (disease) is causing a patient's symptoms and signs.⁹³

One of the difficulties in recognizing diseases is the absence of an accepted metric for establishing new disease entities. Thus, when a possible new set of characteristic symptoms, signs, and laboratory manifestations is described, there is no one method for developing consensus on whether a new disease entity exists.⁹⁴ For example, when the characteristic symptoms, signs, and laboratory test results of acquired immunodeficiency syndrome (AIDS) were first described in the early 1980s, prior to the identification of the human immunodeficiency virus (HIV), there was considerable controversy over whether a new disease entity had manifested itself. Development of a test for infection with the specific virus cemented recognition of the disease. There have also been analogous, but largely unresolved, controversies over chronic fatigue syndrome, fibromyalgia, multiple-chemical sensitivity, and Gulf War syndrome.⁹⁵

93. For an example of how a symptom may be common to a number of diseases, compare Jeffrey A. Gelfand & Charles A. Dinarello, *Fever and Hyperthermia*, in 1 Principles of Internal Medicine, *supra* note 42, at 84, 88 tbl.17-1; Elaine T. Kaye & Kenneth M. Kaye, *Fever and Rash*, in 1 Principles of Internal Medicine, *supra* note 42, at 90, 91-96 tbl.18-1; Robert B. Daroff & Joseph B. Martin, *Faintness, Syncope, Dizziness, and Vertigo*, in 1 Principles of Internal Medicine, *supra* note 42, at 100, 100 tbl.20-1; Patrick T. O'Gara & Eugene Braunwald, *Approach to the Patient with a Heart Murmur*, in 1 Principles of Internal Medicine, *supra* note 42, at 198, 199 tbl. 34-1.

94. See, e.g., Khalida Ismail et al., *Is There a Gulf War Syndrome?*, 353 *Lancet* 179, 179 (1999) ("For an illness to be recognised as a new disorder it must be sufficiently different from other recognised disorders . . . There is no formal process to investigate whether a set of symptoms are unique to a new illness."). For an explication of several methods that can be used to determine whether a new disease entity exists, see also David H. Wegman et al., *Invited Commentary: How Would We Know a Gulf War Syndrome If We Saw One?*, 146 *Am. J. Epidemiology* 704 (1997).

95. The recognition of multiple-chemical sensitivity as a disease was at issue in *Zwillinger v. Garfield Slope Housing Corp.*, No. CV 94-4009, 1998 WL 623589 (E.D.N.Y. Aug. 17, 1998). See also Howard M. Kipen & Nancy Fiedler, *Invited Commentary: Sensitivities to Chemicals—Context and Implications*, 150 *Am. J. Epidemiology* 13 (1999).

B. Diagnosis

Clinical diagnosis has been described as a process of “iterative hypothesis testing.” It relies on both analysis and synthesis of data. When making a diagnosis, a clinician makes inferences about types of malfunctions of the patient’s organs or chemistry that would lead to the observed abnormalities. The basis for the inferences are facts (information) that have been collected about the patient. The clinician applies inferential (also known as inductive) reasoning, considering the specific historical, physical, and laboratory facts, until a diagnosis that coherently describes the patient’s condition can be hypothesized. Such a working diagnosis is sometimes called, or corresponds to, a syndrome, which is a clustering of signs and symptoms of abnormal function.⁹⁶ Syndromes and working diagnoses do not identify precise underlying internal causes. To arrive at an underlying internal cause, the physician must process the multiple symptoms and signs from the working diagnosis into a single diagnosis or disease, such as multiple vascular strokes as an explanation for dementia.

In the process of performing a differential diagnosis, the physician determines which of two or more diseases with similar clinical findings is the one that the patient is suffering from.⁹⁷ The physician does this by developing a list of all of the possible diseases that could produce the observed signs and symptoms, and then comparing the expected clinical findings for each with those exhibited by the patient.⁹⁸

While working through a differential diagnosis, the clinician will often have generated a number of diagnostic hypotheses of what specific underlying diseases might be the cause of the patient’s problem. Initially these hypotheses are colored by the patient’s demographic characteristics (e.g., age, gender, race) as well as appearance and chief (or presenting) complaints, because all of these

96. For example, dementia is a syndrome of impaired memory, thinking, language, and judgment (all of which are symptoms that can actually also be measured as signs) related to destruction or malfunction of specific parts of the brain. In congestive heart failure, shortness of breath (symptom), trouble lying down flat (symptom), swollen ankles (symptom or sign), weight gain (sign), swollen neck veins (sign), crackling noises heard in the lungs (sign), and galloping heart sounds (sign) are attributable to one pathophysiological dysfunction—inadequate pumping of blood by the heart. In Cushing’s syndrome, an abnormally round face (moon face), diabetes mellitus (high blood sugar causing a syndrome of its own), bone thinning (osteoporosis), and high blood pressure are all due to excessive amounts of certain hormones, glucocorticoids, resulting from either excess glandular secretion by the body or overuse as a medication. Fauci et al., *supra* note 56, at 3.

97. See Stedman’s Medical Dictionary 474 (26th ed. 1995) (definition of *differential diagnosis*); Kassirer & Kopelman, *supra* note 48, at 16.

98. Diagnosis is at issue in many kinds of cases, including medical malpractice and other personal injury claims. See, e.g., Bates et al., *supra* note 49, at 635–48; *Samuels v. Secretary of Dep’t of Health & Human Servs.*, No. 91-127V, 1995 WL 809884 (Fed. Cl. Aug. 1, 1995) (diagnosis of a neurological disorder at issue in claim under the National Vaccine Injury Compensation Program); *Alex v. Dr. X*, 692 So. 2d 499 (La. Ct. App. 1997) (diagnosis of tuberculosis at issue).

affect the probabilities of developing specific illnesses and are also easily observable.⁹⁹ For instance, lung cancer and heart attacks are relatively rare in individuals under age 40 and would not usually be at the top of a list of preliminary hypotheses for patients in this age group even if they did complain of cough or chest pain, respectively. Sometimes the diagnostic hypotheses will be greatly influenced by a single piece of physical or laboratory data. As the physician develops and considers hypotheses during the history-taking, he or she may modify the questions asked of the patient to probe specific areas that test and rule out a succession of hypotheses.¹⁰⁰

The initial, or working, diagnosis provides a context or template for gathering further information and specifying tests to confirm or refute the working diagnosis. Each working diagnosis implies the presence of certain symptoms or test results and the absence of others if the patient has the given disorder. The physician modifies and refines the working diagnosis as additional information is gathered, generating new diagnoses as the old ones are pushed aside by inconsistent findings.¹⁰¹ In essence a physician thinks the patient probably has Condition X and orders tests that will verify or refute this diagnosis. If the diagnosis is refuted, the physician reshapes the diagnostic hypothesis and orders additional tests that may be required. Experienced physicians select and test the most probable hypothesis first. This is the generally accepted (though seldom formally acknowledged) methodology that physicians employ to arrive at a diagnosis.

The goal of the clinician is to arrive at a diagnosis that can be used to develop a rational plan for further investigation, observation, or treatment, and ultimately to predict the course of the patient's illness (prognosticate). To do this, the clinician must verify or validate the diagnostic hypothesis.¹⁰² Validation of a diagnostic hypothesis requires an assessment of coherency of the hypothesis (i.e., do the patient's physiology, risk factor profile, and complications sufficiently match those expected from the suspected disease?). The presence of each such symptom or sign that matches those expected for a given condition is known as a "pertinent positive" for that diagnosis. Determining the adequacy of the diagnostic hypothesis requires assessment of the converse (i.e., does the suspected disease encompass or satisfactorily explain enough of the patient's normal and abnormal findings?). The absence of each symptom or sign characteristic of a particular condition is known as a "pertinent negative" for that condition and tends to make that condition less likely. Finally, the principle of parsimony requires asking whether the suspected disease is a simple explanation for all of the patient's important findings. Although it is not always correct or possible, an

99. See Kassirer & Kopelman, *supra* note 48, at 7; Bates et al., *supra* note 49, at 637–38.

100. See Kassirer & Kopelman, *supra* note 48, at 9; Bates et al., *supra* note 49, at 646–47.

101. See Kassirer & Kopelman, *supra* note 48, at 11, 32–33.

102. See *id.* at 32–33.

explanation of all of the patient's signs and symptoms with a single underlying condition or disease process is desirable. Of course, some patients, especially the elderly, may have more than one underlying disease (e.g., heart disease, osteoporosis, and chronic renal failure). Sometimes two common conditions will be a more logical explanation than one complex and unusual disease that could also explain all of the observed manifestations. Physicians also consider competing hypotheses, to ascertain that no other disease is present that better explains the current hypothesis or findings.¹⁰³

All diagnostic hypotheses represent probabilistic judgments that are based on observed medical facts that have variable probabilities of being correct. Each fact (symptom, sign, or test abnormality) also has only a variable probability of being found in a given condition that is typically characterized by its presence. If the diagnosis is based on inconsistent records or observations, the physician should explain how the inconsistencies affected the assessment being offered.¹⁰⁴

C. Probabilistic Basis of Diagnosis

Medical diagnosis is not an exact science. As indicated above, physicians make probabilistic judgments on a day-to-day basis, even when they can supplement a patient's history and physical with the results of extensive laboratory tests. Laboratory, clinical, and physiological tests are important for any given disease and may be characterized in terms of their "sensitivity" and "specificity," which indicate the usefulness of the test results in making a particular disease diagnosis. For a given test, sensitivity, which is also known as the true positive rate, is the percentage of positive tests in patients who actually have the disease. Test results in those who have a disease but are incorrectly identified as not having the disease because of the test's insensitivity are "false negatives." Thus, a test that is positive in 80% of actual cases of asthma (80% sensitivity) will fail to indicate asthma, or be falsely negative, in 20% of actual cases.

Specificity is the percentage of negative test results in individuals who are free of a given disease, also known as the true negative rate. Test results in those who are free of the disease who are incorrectly identified as having the condition are "false positives." Thus, a test that indicates abnormal bronchial reactivity in 15% of individuals without asthma would have a false positive rate of 15%; their test results were positive, but they are free of the condition.¹⁰⁵ For example, a physician may order a chest x-ray as a test to rule out lung cancer for a 60-year-old man who just began to cough up flecks of blood but has a normal physical exam.

103. See *id.*

104. See *id.* at 16; Bates et al., *supra* note 49, at 635–74.

105. See Bates et al., *supra* note 49, at 641; Goldman, *supra* note 56, at 10–11; Kassirer & Kopelman, *supra* note 48, at 18–19; Michael D. Green et al., Reference Guide on Epidemiology § V.H, and David H. Kaye & David A. Freedman, Reference Guide on Statistics §§ III.A.3, IV.B.2, IV.C, in this manual.

If the x-ray does not show any evidence of lung cancer (is negative for a finding consistent with lung cancer), that diminishes the probability of lung cancer, but it does not rule it out. A cancer may actually be present but not show up on the x-ray because it is too small or because it is in an unobservable location. The physician will be aware of the possibility of such a false-negative result and, especially for a high-risk individual (see below), may order a follow-up exam in a few months or immediately order a more sensitive test, such as a CAT scan or bronchoscopy. A false-positive result that was due to the imperfect specificity of the chest x-ray would occur if the x-ray showed an abnormality that suggested cancer, but when biopsied (the gold standard of tissue diagnosis) turned out to be an old scar resulting from a dormant injection.

Sensitivity and specificity provide information about the usefulness of a piece of data (a symptom, sign, or test) for diagnostic reasoning in any population of patients. However, they do not give complete information for predicting or excluding disease in individual patients. For that, information about the patient, and the population that he or she represents, must be incorporated.¹⁰⁶

Physicians must interpret the predictive value of a test in assessing the presence or absence of disease in a specific patient. The predictive value of a test for a specific individual is based not only on the sensitivity and specificity of the test, but also on the prevalence of disease in the population from which the patient comes, such as age group, gender group, racial group, and groups with occupational exposures.¹⁰⁷ In the previous example, if the 60-year-old man was a smoker and had been occupationally exposed to a lung carcinogen, such as asbestos, a negative x-ray might be viewed more suspiciously than if he was free of additional risks.

If sensitivity and specificity are known in general for a particular test, sign, or symptom, and the overall prevalence of the condition is known for the population group from which the patient comes, then one can actually calculate a good approximation of the predictive value of the test, sign, or symptom for that person and condition according to a rule known as Bayes' theorem. These calculations have actually been translated into nomograms (tables) for general use.¹⁰⁸ Few clinicians actually calculate such probabilities, but they use an analogous reasoning process on a routine basis. This Bayesian reasoning is a major tool of

106. See Bates et al., *supra* note 49, at 645-46.

107. "Positive predictive value" is the frequency of disease among patients with positive results, and "negative predictive value" is the frequency of absence of disease among individuals with negative test results. For a test with a given sensitivity and specificity, positive predictive value is higher when a condition is common in a population, and negative predictive value is higher when the condition is rare. Bates et al., *supra* note 49, at 642. See also David H. Kaye & David A. Freedman, Reference Guide on Statistics §§ III.A.3, IV.C, in this manual.

108. See Swartz, *supra* note 50, at 675-76 & fig.25-3. See generally David H. Kaye & David A. Freedman, Reference Guide on Statistics § IV.D, app., in this manual.

physicians in thinking through a differential diagnosis. For instance, heart attacks are very rare in 25-year-olds and relatively more common in 75-year-olds. In analyzing a patient with chest pain and borderline abnormal EKG changes, the physician is much more likely to suspect a heart attack as the cause of the pain in the 75-year-old, and admit the patient to a hospital, at least for monitoring.¹⁰⁹

Diagnostic reasoning is usually more complex than the examples given because it is simultaneously based on multiple symptoms, signs, and test results (e.g., family history, physical exam). These findings are not all truly independent of one another, thus preventing straightforward addition of the probabilities as in a Bayesian model. This lack of independence limits the ability of physicians to make accurate calculations of the results of multiple simultaneous predictive values. However, physicians must routinely make such estimations, albeit often implicitly and without numerical quantification, as part of clinical care. Thus, physicians frequently rely on the principles of Bayesian reasoning when deciding on a diagnosis.¹¹⁰ Doctors combine probabilities of disease (prevalence) with their knowledge of the frequency of signs and symptoms in a given disease and competing diseases to progressively modify and ultimately arrive at their view of the likelihood of the disease under consideration.

D. Causal Reasoning

During the diagnostic process, the physician employs causal reasoning to integrate the various clinical variables into an understanding of the cause-and-effect relationships among them, based on an understanding of how the various systems of the human body interact and react to external stressors. Causal reasoning allows the clinician to conceptualize the possible course of the patient's disease and predict the effects of treatment, and is important in evaluating the coherency of a diagnosis. For example, if the patient is experiencing chest pain on exertion and has a history of high blood cholesterol levels, the physician might posit a causal model that involves cholesterol plaque substantially obstructing coronary arteries, resulting in inadequate blood flow to the heart muscle during exercise causing chest pain. This model might then suggest that the physician first investigate the degree of occlusion in the coronary arteries, and second

109. The positive predictive value of a symptom of chest pain for a heart attack is very low in a 25-year-old because advanced atherosclerotic cardiovascular disease is rare in this age group and other causes of chest pain are more common. Similarly, interstitial fibrosis on a chest x-ray, whatever the x-ray's sensitivity and specificity for a true underlying finding of pathologic fibrosis, has a much higher predictive value for a diagnosis of asbestosis in a person known to come from an asbestos-exposed population than in someone with no known occupational exposure to asbestos.

110. See Kassirer & Kopelman, *supra* note 48, at 19–24; Steven N. Goodman, *Toward Evidence-Based Medical Statistics. 2: The Bayes Factor*, 130 *Annals Internal Med.* 1005, 1011 (1999).

consider measures such as smoking cessation, dietary modification, medications, and even angioplasty or surgery if the level of occlusion proves to be substantial and a likely explanation for the pain.

As the process of refinement of diagnostic hypotheses unfolds, the consideration of several causal models may be necessary, because consistency of the model with observed findings does not necessarily prove that a model is correct. In the example above, another model that would explain the findings is exposure to high levels of carbon monoxide from a faulty furnace at home, producing a blood carboxyhemoglobin level of 18% (the normal for a nonsmoker is less than 1%) and reducing the blood's oxygen-carrying capacity. In conjunction with only mild coronary artery obstruction by plaque, this exposure then leads to inadequate oxygen delivery to the heart muscle and chest pain. The model combines general causation models for coronary artery disease with information on the levels of carbon monoxide and coronary artery obstruction specific to this patient. Thus, the physician applies general medical knowledge about the relationship of various factors to symptoms and then refines the appropriate causal model in accordance with the specific patient's condition. Although carbon monoxide intoxication can cause chest pain that is due to inadequate oxygen delivery to the heart, it requires a blood carboxyhemoglobin level of at least 5% to 10%, and its impact is enhanced by the presence of underlying mechanical obstruction of the coronary arteries. Hence, the physician must usually consider and assess alternative and more specific causal models before accepting a particular model as the preferred explanation. Like the probabilistic reasoning described above, this kind of reasoning is rarely made explicit.

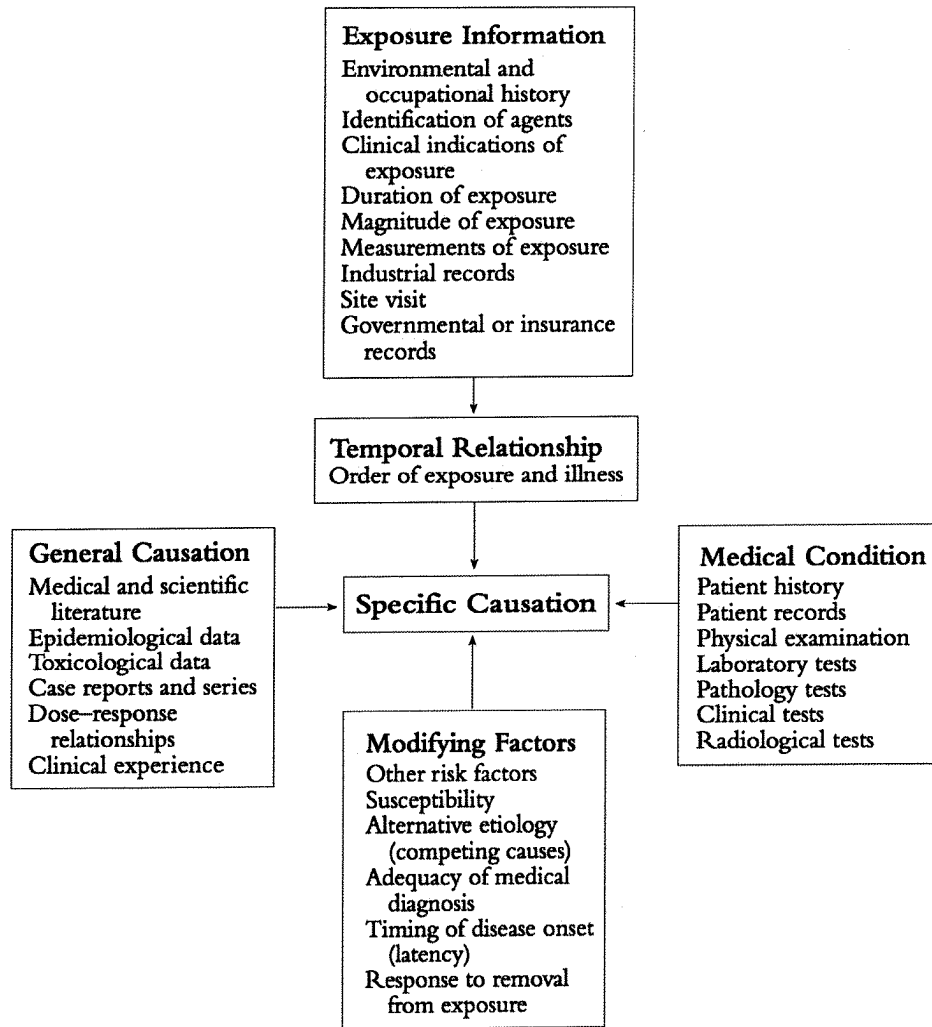
E. Evaluation of External Causation

For the physician, both causal and probabilistic reasoning are the basis for establishing external causation, which is the relationship between environmental factors (work, chemical exposures, lifestyle, medications) and illness, as well as for making the more common analysis of internal causation as discussed earlier in section IV.B. The physician may be asked to determine external causation by the patient or a third party, such as a lawyer, insurance company, or governmental agency. A key element of determining causation is gaining access to all information available about the patient's condition.

Figure 1 provides examples of the diverse types of information that may be available for review in determining external causation. In any given case, much of the listed information is normally not available.¹¹¹ Determining external causation also generally occurs in a stepwise fashion. In the first step the physician

111. For a somewhat different illustration of the interaction of such factors, see Cullen et al., *supra* note 19, at 230 fig.18-2.

Figure 1. Determining External Causation



must establish the characteristics of the medical condition. Second, he or she carefully defines the nature and amount of the environmental exposure. The third step is to demonstrate that the medical and scientific literature provides evidence that in some circumstances the exposure under consideration can cause the outcome under consideration. This step is synonymous with establishment of general causation. As part of this step, the clinician attempts to establish the relationship between dose and response, including whether thresholds exist, ultimately defining the clinical toxicology of the exposure. The fourth step is to

apply this general knowledge to the specific circumstances of the case at hand, incorporating the specifics of exposure, mitigating or exacerbating influences, individual susceptibilities, competing or synergistic causes, and any other relevant data.¹¹²

Many conditions resulting from toxic exposures are similar or identical in clinical manifestations to conditions arising from nontoxic causes.¹¹³ Physicians rely on their training and expertise as clinicians and scientists when considering the medical and scientific literature as well as information about a patient's condition to best determine causality in a particular patient. Definitive tests for causality are actually rare,¹¹⁴ and physicians must almost always use an element of judgment in determining the relationship between exposure and disease in a

112. Many cases involving issues of external causation have involved witnesses who testify to having arrived at an opinion on cause through a process of ruling out or eliminating other causes, a process frequently referred to by the courts and witnesses as "differential diagnosis" or "differential etiology" (for explanation of the differences between medical and legal uses of terminology, see section I.B., *supra*). Not infrequently, this form of testimony is implicitly or explicitly offered to satisfy the applicable burden of proof on causation. The relationship between the "more probable than not burden of proof" and "differential diagnosis" was discussed in *Cavallo v. Star Enterprise*, 892 F. Supp. 756 (E.D. Va. 1995), *aff'd in part, rev'd in part*, 100 F.3d 1150 (4th Cir. 1996), *cert. denied*, 522 U.S. 1044 (1998), a case in which the witness opined on whether a spill of aircraft fuel caused the plaintiff's rash. The court explained, "The process of differential diagnosis is undoubtedly important to the question of 'specific causation.' If other possible causes of an injury cannot be ruled out, or at least the probability of their contribution to causation minimized, then the 'more likely than not' threshold for proving causation may not be met." *Id.* at 771 (footnote omitted).

Courts differ on whether opinion based on such "differential diagnosis" or "differential etiology" of cause is admissible. Compare *Westberry v. Gummi*, 178 F.3d 257, 263 (4th Cir. 1999) (reliable "differential diagnosis" provides a valid basis for an expert opinion), *Anderson v. Quality Stores, Inc.*, 181 F.3d 86 (4th Cir. 1999) (per curiam) (opinion on spray paint causing pulmonary problems should have been admitted based on "differential diagnosis" and temporal relationship), *In re Paoli R.R. Yard PCB Litig.*, 35 F.3d 717 (3d Cir. 1994) (approving opinion based on "differential diagnosis"), *cert. denied*, 513 U.S. 1190 (1995), *McCulloch v. H.B. Fuller Co.*, 61 F.3d 1038, 1042-44 (2d Cir. 1995) (accepting opinion based on "differential etiology"), and *Zuchowicz v. United States*, 140 F.3d 381, 387-91 (2d Cir. 1998) (accepting witness's "differential etiology" opinion of causes of pulmonary hypertension), with *Raynor v. Merrell Pharms., Inc.*, 104 F.3d 1371, 1375-76 (D.C. Cir. 1997) ("differential diagnosis" of cause of birth defect inadmissible where general causation proof absent), *Cavallo v. Star Enter.*, 892 F. Supp. 756, 771-73 (E.D. Va. 1995) ("differential diagnosis" of cause inadmissible where general causation not established), *aff'd in part, rev'd in part*, 100 F.3d 1150 (4th Cir. 1996), *cert. denied*, 522 U.S. 1044 (1998), *Hall v. Baxter Healthcare Corp.*, 947 F. Supp. 1387, 1412-14 (D. Or. 1996) ("differential diagnosis" and specific causation require proof of general causation; witness did not explain how he ruled out other causes), *Haggerty v. Upjohn Co.*, 950 F. Supp. 1160, 1166-67 (S.D. Fla. 1996) ("differential diagnosis" testimony inadmissible where another cause could explain all of plaintiff's symptoms), *aff'd*, 158 F.3d 588 (11th Cir. 1998) (unpublished table decision), and *Austin v. Children's Hosp. Med. Ctr.*, 92 F.3d 1185 (6th Cir. 1996) (unpublished table decision) (text at No. 95-3880, 1996 WL 422484, at *3 (6th Cir. July 26, 1996)) (expert unable to show that defendant, rather than other sources, "more likely than not" infected plaintiff's son with fatal virus).

113. See, e.g., Herbert Y. Reynolds, *Interstitial Lung Disease*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 1460, 1460-63 & tbl.259-1.

114. For a discussion of the difficulty of establishing causation, see Feinstein, *supra* note 40, at 266-74.

given patient. For instance, if a substance is suspected to cause an allergic or toxic condition, it may be necessary for diagnostic purposes to remove a patient from the workplace on a trial basis. On the other hand, determinations of external causation in patients with cancer may be irrelevant to treatment decisions as treatment is usually unaffected by assignment of cause.¹¹⁵

Physicians use both causal and probabilistic reasoning in determining both internal and external causation in regard to a particular illness. Methods for determination of some special external causes of disease may be found in occupational and environmental medical texts and journals¹¹⁶ and generally are analogous to methods used for assessment of internal disease causation.¹¹⁷ The difference is essentially in the body of medical, toxicological, epidemiological, and industrial hygiene knowledge that is relevant and needs to be incorporated.

For instance, in an elderly patient with chronic shortness of breath, the treating physician may use differential diagnosis to determine that chronic bronchitis is the best explanation as the underlying cause of symptoms, having excluded heart disease, anemia, lung fibrosis, and emphysema. The treating physician will rarely consider the external causes of the chronic bronchitis, beyond consideration of whether the patient smoked cigarettes.¹¹⁸ The specific contribution of environmental or workplace exposures is rarely assessed as a part of clinical care in an elderly nonworking patient, since it does not affect diagnosis, treatment, and prognosis of this particular disease.¹¹⁹ However, such determination of external causation may be essential to determination of a contested workers' compensation award.¹²⁰

The key factor for the courts to recognize is that, while similar underlying reasoning is used in determination of both internal and external causation, and

115. However, exceptions may be cited, including the need to determine if there is a genetic (familial) risk of cancer that may require notification and screening of family members (e.g., certain forms of colon cancer and breast cancer), or if other family members or workers may be at remediable risk.

116. See, e.g., Howard Hu & Frank E. Speizer, *Specific Environmental and Occupational Hazards*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 2521, 2521–22; Linden & Lovejoy, *supra* note 76, at 2523–25; Hu, *supra* note 87, at 2565–67.

117. See, e.g., peer review case studies published by the Agency for Toxic Substances and Disease Registry (ATSDR), a branch of the Centers for Disease Control and Prevention. For the most part, these case studies discuss the diagnosis and treatment of environmental illness, and in a number of instances discuss the reasoning involved in assessing the causal role of an environmental exposure. Selected ATSDR case studies are included in *Environmental Medicine: Integrating a Missing Element into Medical Education*, *supra* note 57, at app. C.

118. See Eric G. Honig & Ronald H. Ingram, Jr., *Chronic Bronchitis, Emphysema, and Airways Obstruction*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 1451, 1452.

119. In a working patient, the contribution of workplace conditions may be taken into account in advising the patient on the advisability of returning to or remaining in the work environment if there are conditions present that may exacerbate the patient's respiratory condition. *Id.* at 1456.

120. See, e.g., *Fiore v. Consolidated Freightways*, 659 A.2d 436 (N.J. 1995).

physicians routinely make limited determinations of external causation, many of the facts relevant to a determination of external causation rely on a body of scientific literature that is not routinely used by treating physicians. As a corollary, an expert's opinion on diagnosis and his or her opinion on external causation should generally be assessed separately, since the bases for such opinions are often quite different.

1. Exposure

Critical to a determination of causation is characterizing exposure. Exposure to a toxic substance can sometimes be established by a review of the patient's history and various available indicators of exposure, as discussed in section III. There are four "cardinal" pieces of exposure information:

1. The material or agent in the environmental exposure should be identified.
2. The magnitude or concentration of an exposure should be estimated, including use of clinical inference.
3. The temporal aspects of the exposure should be determined—whether the exposure was short-term and lasted a few minutes, days, weeks, or months, or was long-term and lasted for years. Similarly, the latency between exposure and disease onset is often critical.
4. If possible, the impact on disease or symptoms should be defined.¹²¹

In many instances, the desired information will be incomplete,¹²² but it can often be inferred from the literature that a given amount of time in a particular industry is well associated with disease-producing potential. Progressive pulmonary fibrosis (accelerated silicosis) can develop in as little as ten months in workers involved in manufacturing abrasive soaps, tunneling in rock that has a high quartz content, or carrying out sandblasting in small, enclosed spaces, although

121. See Cullen et al., *supra* note 19, at 224.

122. The courts vary in the degree of certainty they require in exposure estimates. Many courts accept exposure evidence as sufficient without proof of specific levels. See, e.g., *Kannankeril v. Terminix Int'l, Inc.*, 128 F.3d 802, 808–09 (3d Cir. 1997). Other courts have required more particularized proof. See, e.g., *Curtis v. M&S Petroleum, Inc.*, 174 F.3d 661, 671–72 (5th Cir. 1999) (exposure evidence sufficient for opinion on causation where expert testified that refinery workers were exposed to at least 100 parts per million (ppm), and probably several hundred ppm, of benzene). Based on these measurements, *Curtis* distinguishes another Fifth Circuit case, *Moore v. Ashland Chemical, Inc.*, 151 F.3d 269 (5th Cir. 1998) (en banc), *cert. denied*, 119 S. Ct. 1454 (1999), in which exposure evidence was found insufficient to support an opinion on causation because the expert had a "paucity of facts" on which to base an opinion and did not testify to any specific levels of exposure. 174 F.3d at 670 (quoting *Moore*, 151 F.3d at 279 n.10). Exposure levels have been at issue in a number of other cases. See, e.g., *In re Paoli R.R. Yard PCB Litig.*, 916 F.2d 829 (3d Cir. 1990), *cert. denied*, 499 U.S. 961 (1991); *In re "Agent Orange" Prod. Liab. Litig.*, 611 F. Supp. 1223 (E.D.N.Y. 1985), *aff'd*, 818 F.2d 187 (2d Cir. 1987), *cert. denied*, 487 U.S. 1234 (1988).

simple silicosis is much more commonly a chronic illness resulting from years of exposure.¹²³ In other situations, exposure estimates will be based on methods beyond the scope of medical expertise, such as physical or chemical analyses, or chemical fate-and-transport modeling (i.e., using mathematical models to project the movement of chemicals in air, water, and soil).

In determining causation, the physician may have particular insight into clinical clues related to exposure, such as clinical indicators of degree of exposure, temporal relationships, and the effect of removal from the toxic substance.¹²⁴ The physician also has particular insight into the role that preexisting illnesses may play in causing an exacerbation, recurrence, or complication of a clinical condition independent of any exposure to toxic products, or in concert with a toxic exposure.¹²⁵

2. Reviewing the Medical and Scientific Literature

After characterizing exposure and the nature of the patient's disease, the physician expert witness must determine if the medical and research literature supports a determination of environmental causation.¹²⁶ The research literature in-

123. See Speizer, *supra* note 59, at 1431–32.

124. An appropriate temporal relationship—the time that elapsed between exposure and onset of disease or symptoms—is a necessary but often insufficient basis for an opinion on causation. Courts frequently warn against reasoning based on the premise “*post hoc, ergo propter hoc.*” See, e.g., *Whiting v. Boston Edison Co.*, 891 F. Supp. 12, 23 n.52 (D. Mass. 1995) (rejecting opinion on cause of acute lymphocytic leukemia following radiation exposure). In some cases, courts have permitted opinions on causation based primarily on temporal proximity between exposure and development of the disease, but many of these cases involved symptoms or diseases that closely followed the exposure asserted to be the cause. See, e.g., *Curtis v. M&S Petroleum, Inc.*, 174 F.3d 661, 670 (5th Cir. 1999); *Anderson v. Quality Stores, Inc.*, 181 F.3d 86 (4th Cir. 1999) (unpublished table decision) (text at No. 98-2240, 1999 WL 387827, at *2 (4th Cir. June 14, 1999) (per curiam)). Other courts have excluded opinions on causation based primarily on temporal proximity. In *Moore v. Ashland Chemical, Inc.*, 151 F.3d 269, 278 (5th Cir. 1998) (en banc), *cert. denied*, 119 S. Ct. 1454 (1999), for example, the Fifth Circuit found that the expert's reliance on the temporal relationship between the exposure and the onset of symptoms was entitled to little weight in the absence of supporting medical literature. See also *Rosen v. Ciba-Geigy Corp.*, 78 F.3d 316, 319 (7th Cir.) (rejecting expert testimony on nicotine patch as cause of heart attack that occurred after three days of wearing patch), *cert. denied*, 519 U.S. 819 (1996); *Porter v. Whitehall Labs., Inc.*, 9 F.3d 607, 614 (7th Cir. 1993) (rejecting clinical observations and temporal relationship between drug ingestion and renal failure as bases for opinion on causation where scientific studies unavailable). On occasion, a temporal relationship that does not fit the expected pattern may be a basis for ruling out the suspected cause. See, e.g., *Heller v. Shaw Indus., Inc.*, 167 F.3d 146, 157–58 (3d Cir. 1999) (temporal relationships may be important in supporting an opinion on causation, but expert's reliance on temporal relationship is flawed in this case). See generally Speizer, *supra* note 59, at 1429–36; Honig & Ingram, *supra* note 118, at 1452, 1456.

125. See Cullen et al., *supra* note 19, at 227.

126. The courts differ on the question whether the witness giving an opinion on causation must support his or her opinion with references to medical or scientific studies supporting a causal link between the toxic exposure and the plaintiff's disease. A number of courts have answered this question in the affirmative. See, e.g., *Moore v. Ashland Chem., Inc.*, 151 F.3d 269, 277–78 (5th Cir. 1998) (en banc), *cert. denied*, 119 S. Ct. 1454 (1999); *Rosen v. Ciba-Geigy Corp.*, 78 F.3d 316, 319 (7th Cir.)

cludes epidemiological studies and toxicology studies. The physician should be guided by the methods set forth in the Reference Guides on Epidemiology and Toxicology in evaluating this literature and its relevance to the patient's exposure and condition.¹²⁷

Physicians also have access to case reports or case series in the medical literature. These are reports in medical journals describing clinical events involving one individual or a few individuals. They report unusual or new disease presentations, treatments, or manifestations, or suspected associations between two diseases, effects of medication, or external causes of diseases. For example, the association between asbestos and lung cancer was first reported in a 1933 case report, although the first controlled epidemiological study on the association was not published until the 1950s.¹²⁸ There are a number of other instances in which epidemiological studies have confirmed associations between a specific exposure and a disease first reported in case studies (e.g., benzene and leukemia; vinyl chloride and hepatic angiosarcoma),¹²⁹ but there are also instances in which controlled studies have failed to substantially confirm the initial case reports (e.g., the alleged connection between coffee and pancreatic and bladder cancer or the infectious etiology of Hodgkins disease).¹³⁰

(witness cited no scientific or medical literature, or other explanation of asserted causal relationship between nicotine patch and heart attack), *cert. denied*, 519 U.S. 819 (1996); *Porter v. Whitehall Labs., Inc.*, 9 F.3d 607, 615 (7th Cir. 1993) (medical literature did not establish link between ibuprofen and plaintiff's kidney ailment; medical theories had not been tested). Other courts have upheld the admission of medical opinion based solely on clinical observations and reasoning, sometimes with reference to the physician's experience with similar kinds of patients or cases. *See, e.g.*, *Heller v. Shaw Indus., Inc.*, 167 F.3d 146, 153–57 (3d Cir. 1999); *Westberry v. Gummi*, 178 F.3d 257, 262–66 (4th Cir. 1999) (affirmed trial court's admission of expert testimony on talc as cause of plaintiff's sinus problems despite absence of supporting medical literature); *Fadelalla v. Secretary of the Dep't of Health & Human Servs.*, No. 97-05730, 1999 WL 270423, at *6 (Fed. Cl. Apr. 15, 1999) (while clinical experience may be sufficient to establish causal relationship, in this case expert had insufficient clinical experience on which to base an opinion on causation); *Becker v. National Health Prods., Inc.*, 896 F. Supp. 100, 103 (N.D.N.Y. 1995) (absence of published literature on relationship between diet supplement and diverticulosis not fatal to plaintiff's case where expert relied on "differential etiology").

127. *See* Michael D. Green et al., Reference Guide on Epidemiology, §§ V–VII, and Bernard D. Goldstein & Mary Sue Henifin, Reference Guide on Toxicology, §§ III–V, in this manual.

128. *See* Michael Gochfeld, *Asbestos Exposure in Buildings*, in *Environmental Medicine*, *supra* note 19, at 438, 440.

129. *See* Michael Gochfeld, *Chemical Agents*, in *Environmental Medicine*, *supra* note 19, at 592, 600 (vinyl chloride); Howard M. Kipen & Daniel Wartenberg, *Lymphohematopoietic Malignancies*, in *Textbook of Clinical Occupational and Environmental Medicine* 555, 560 (Linda Rosenstock & Mark R. Cullen eds., 1994) (benzene).

130. Kristin E. Anderson et al., *Pancreatic Cancer*, in *Cancer Epidemiology and Prevention* 725, 740–41 (David Schottenfeld & Joseph F. Fraumeni, Jr., eds., 2d ed. 1996); Debra T. Silverman et al., *Bladder Cancer*, in *Cancer Epidemiology and Prevention*, *supra*, at 1156, 1165–66.

Case reports lack controls and thus do not provide as much information as controlled epidemiological studies do.¹³¹ However, case reports are often all that is available on a particular subject because they usually do not require substantial, if any, funding to accomplish, and human exposure may be rare and difficult to study. Causal attribution based on case studies must be regarded with caution. However, such studies may be carefully considered in light of other information available, including toxicological data.¹³²

3. Clinical Evaluation of Information Affecting Dose–Response Relationships

Assessing the role of external causes in the patient's condition requires the integration of the information described in the preceding sections, with particular attention to dose–response relationships. The toxicological law of dose–response, that is, that “the dose makes the poison,” refers to the general tendency for greater doses of a toxin to cause greater severity of responses in individuals, as well as greater frequency of response in populations.¹³³ Clinically, there are some instances in which the general rule does not hold. For agents that cause an allergic response through an immunologic mechanism, the dose–response relationship is often less straightforward. Many people who are not prone or able to develop an allergic reaction, for genetic or other reasons, will not respond adversely to the substance at any dose. However, those who are susceptible are more likely to become specifically reactive (sensitized) to the specific agent as the dose increases. After sensitization has occurred, severe reactions may occur with exposures that are much lower than the previous level required for sensitization.¹³⁴

Although some diseases (e.g., pneumonia that is due to influenza) are frequently considered to be unifactorial, the possibility of multiple causes of a clini-

131. See generally Michael D. Green et al., Reference Guide on Epidemiology § II.A, in this manual.

132. See Cullen et al., *supra* note 19, at 226. Courts have given varying treatment to case reports. Compare Haggerty v. Upjohn Co., 950 F. Supp. 1160, 1165 (S.D. Fla. 1996) (case reports are “no substitute for a scientifically designed and conducted inquiry” (citing Casey v. Ohio Med. Prods., 877 F. Supp. 1380, 1385 (N.D. Cal. 1995))), *aff'd*, 158 F.3d 588 (11th Cir. 1998) (unpublished table decision), and Hall v. Baxter Healthcare Corp., 947 F. Supp. 1387, 1411 (D. Or. 1996) (case reports “cannot be the basis of an opinion based on scientific knowledge”), with Pick v. American Med. Sys., Inc., 958 F. Supp. 1151, 1160–62, 1178 (E.D. La. 1997) (case studies on gel implants admissible in case on penile implant; theory developed by single physician not admissible), Glaser v. Thompson Med. Co., 32 F.3d 969, 975 (6th Cir. 1994) (ordering trial based on witness who relied on case reports and his own research in rendering opinion on diet pills as cause of intracranial bleeding and fall), and Cella v. United States, 998 F.2d 418, 426 (7th Cir. 1993) (in claim under Jones Act, medical opinion on cause of polymyositis based in part on case reports).

133. See Michael Gochfeld, *Principles of Toxicology*, in Environmental Medicine, *supra* note 19, at 65, 71–72.

134. See Cullen et al., *supra* note 19, at 228–29.

cal condition is a critical concern. At some level most diseases have multiple host and environmental factors that contribute to their presence. A commonly held misconception is that the presence of a nontoxic or other toxic cause for a condition automatically excludes a role for the toxin being considered as an external cause.¹³⁵ While this is sometimes true, in reality the converse can also be true. For example, epidemiology studies dealing with occupational asbestos exposure and cigarette smoking indicate that together they result in much higher rates of lung cancer than either one causes on its own.¹³⁶ Thus, two toxic agents have been found to interact in a synergistic manner so that their combined effects are much greater than even the sum of their individual effects.¹³⁷

Even if causal factors do not interact synergistically, several may contribute in an incremental fashion to a disease and should not be assumed to be mutually exclusive.¹³⁸ Accordingly, the common statement that “alternative causes of disease must be ruled out” before causation is attributed can be more accurately refined to say that “the role of other causes must be adequately considered.” If there is a significant rate of disease of unknown etiology (i.e., other causes or risk factors have not been identified), the determination of external causation

135. Some courts have stated that the plaintiff must offer a “differential diagnosis” to rule out other causes, whereas other courts have rejected such a requirement. *Compare* *Wheat v. Pfizer, Inc.*, 31 F.3d 340, 342 (5th Cir. 1994) (witness failed to rule out hepatitis C and another drug as causes of plaintiff’s liver disease), *Mancuso v. Consolidated Edison Co.*, 967 F. Supp. 1437, 1446 (S.D.N.Y. 1997) (“differential diagnosis” required to rule out other possible causes; plaintiff’s complaints were commonplace ailments), *and* *National Bank of Commerce v. Dow Chem. Co.*, 965 F. Supp. 1490 (E.D. Ark. 1996) (case dismissed because, inter alia, plaintiffs failed to exclude other causes), *aff’d*, 133 F.3d 1132 (8th Cir. 1998), *with* *Curtis v. M&S Petroleum, Inc.*, 174 F.3d 661, 670–72 (5th Cir. 1999) (rejecting requirement of “differential diagnosis” to rule out other causes), *and* *Heller v. Shaw Indus., Inc.*, 167 F.3d 146, 153–57 (3d Cir. 1999) (existence of possible alternative causes goes to weight, not admissibility).

136. Occupational asbestos exposure in nonsmokers increases the risk of lung cancer by a factor of about five, from about 11 per 100,000, for nonsmoking industrial workers not exposed to asbestos to about 58 per 100,000 for nonsmoking asbestos workers; a significant smoking history increases the rate of lung cancer by a factor of at least ten. *See* U.S. Surgeon Gen., U.S. Dep’t of Health & Human Servs., *The Health Consequences of Smoking: Cancer and Chronic Lung Disease in the Workplace* 216 (1985); *see also* Rodolfo Saracci, *The Interactions of Tobacco Smoking and Other Agents in Cancer Etiology*, 9 *Epidemiologic Revs.* 175, 176–80 (1987). Because the effects of smoking and asbestos are multiplicative for lung cancer, the population of smoking asbestos workers has a lung cancer incidence of 5 times 10, or 50 times the background rates, rather than the 15-fold increase predicted by adding the separate risks. *See* U.S. Surgeon Gen., U.S. Dep’t of Health & Human Servs., *supra*, at 216–17.

137. *See* Gochfeld, *supra* note 133, at 73.

138. For example, both occupational asthma and smoking can lead to impairment of pulmonary function, and the presence of one does not rule out a causal role for the other. *See* John H. Holbrook, *Nicotine Addiction*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 2516, 2518; E.R. McFadden, Jr., *Asthma*, in 2 *Principles of Internal Medicine*, *supra* note 42, at 1419, 1419–21. *Cf.* *Wheat v. Pfizer, Inc.*, 31 F.3d 340 (5th Cir. 1994), which involved a victim who died of hepatitis after taking two drugs known to cause liver damage. As to her claim against Pfizer, the manufacturer of one of the drugs, the court found the evidence inadequate, in part, for failing to exclude the possibility that her disease was caused by the other drug. *Id.* at 343. The plaintiff’s witness offered the possibility that the hepatitis

may be complicated.¹³⁹ In general, if a patient is not subject to other known risk factors for a disease, it is more likely that the external cause is a factor in causing the patient's illness.¹⁴⁰

Differences in individual susceptibility are commonly cited as the reason why one person gets sick from an environmental exposure while other persons are not affected. True individual susceptibility is based on genetic differences, such as immunologic reactivity, enzyme metabolism, and gender.¹⁴¹ A number of other acquired factors, such as age, body mass, interacting simultaneous exposures, and preexisting disease, may also contribute to susceptibility.¹⁴² Reliable and accurate information is available about the effects on some diseases of age, body mass, gender, and other factors; however, information on genetic susceptibility is available for only a few diseases, and information on the relation between genetic susceptibility and particular toxic exposures, for even fewer.¹⁴³

resulted from the combined action of the two drugs, which the court rejected because the witness cited no study of the combined effects of the drugs. *Id.* The court also faulted the plaintiff for failing to rule out hepatitis C as a cause of the liver damage, though there was no test for the condition at that time. *Id.* at 342. *But see* *Benedi v. McNeil-PPC, Inc.*, 66 F.3d 1378, 1384 (4th Cir. 1995) (upholding plaintiff's recovery for liver damage caused by Tylenol and alcohol consumption).

139. The problem of unidentified risks (often termed "background cases of unknown etiology") has been recognized in a number of decisions. For example, in *In re Breast Implant Litigation*, 11 F. Supp. 2d 1217 (D. Colo. 1998), the court disapproved of a physician's identification of silicone as the cause of the plaintiff's disease through "differential diagnosis," stating: "As a practical matter, the cause of many diseases remains unknown; therefore, a clinician who suspects that a substance causes a disease in some patients very well might conclude that the substance caused the disease in the plaintiff simply because the clinician has no other explanation." *Id.* at 1230. *See also* *National Bank of Commerce v. Dow Chem. Co.*, 965 F. Supp. 1490 (E.D. Ark. 1996) (rejecting testimony that pesticide caused birth defect where witness acknowledged that causes are unknown for 70% to 80% of birth defects), *aff'd*, 133 F.3d 1132 (8th Cir. 1998); *Whiting v. Boston Edison Co.*, 891 F. Supp. 12 (D. Mass. 1995) (in case alleging radiation caused power plant worker's acute lymphocytic leukemia, witness's acknowledgement that 90% of cases are of unknown cause cast doubt on "differential diagnosis" of cause); *In re "Agent Orange" Prod. Liab. Litig.*, 611 F. Supp. 1223, 1250 (E.D.N.Y. 1985) ("Central to the inadequacy of plaintiffs' case is their inability to exclude other possible causes of plaintiffs' illnesses—those arising out of their service in Vietnam as well as those that all of us face in military and civilian life."), *aff'd*, 818 F.2d 187 (2d Cir. 1987), *cert. denied*, 487 U.S. 1234 (1988). The plaintiff may be able to rely on inferences from epidemiological, toxicological, or other evidence, however. *See* Michael D. Green et al., *Reference Guide on Epidemiology*, and Bernard D. Goldstein & Mary Sue Henifin, *Reference Guide on Toxicology*, in this manual; *In re Hanford Nuclear Reservation Litig.*, No. CV-91-3015-AAM, 1998 WL 775340 (E.D. Wash. Aug. 21, 1998).

140. This kind of reasoning is discussed in *In re Paoli Railroad Yard PCB Litigation*, 35 F.3d 717, 760 n.30 (3d Cir. 1994), *cert. denied*, 513 U.S. 1190 (1995).

141. *See* Stuart M. Brooks et al., *Types and Sources of Environmental Hazards*, in *Environmental Medicine*, *supra* note 19, at 9, 15–17; Daniel W. Nebert et al., *Genetic Epidemiology of Environmental Toxicity and Cancer Susceptibility: Human Allelic Polymorphisms in Drug-Metabolizing Enzyme Genes, Their Functional Importance, and Nomenclature Issues*, 31 *Drug Metabolism Revs.* 467 (1999); Maurizio Taningher et al., *Drug Metabolism Polymorphisms as Modulators of Cancer Susceptibility*, 436 *Mutation Res.* 227 (1999).

142. *See* Karen Reiser, *General Principles of Susceptibility*, in *Environmental Medicine*, *supra* note 19, at 351, 351–52, 358.

143. *See id.* at 357.

In almost all instances, integration of all the above factors into an opinion on causality cannot be reduced to mathematical formulas. There are inevitable gaps in information, as well as lack of knowledge regarding individual characteristics, such as susceptibility and resistance. Thus, clinical judgment is critical to opinions on diagnosis and causation for the individual patient even when the scientific population basis for general causation may be quite strong.

V. Treatment Decisions

Following diagnosis, most physicians are concerned with applying appropriate treatment to either cure or ameliorate a patient's condition. Such treatment may be surgical (e.g., removal of a diseased organ), ablative (e.g., radiotherapy aimed at a tumor), chemotherapeutic (e.g., use of pharmacological agents with a host of different actions), rehabilitative (e.g., physical therapy), interdictive (e.g., removal of the patient from a toxic or allergenic exposure), behavioral (e.g., counseling), or something else.¹⁴⁴ Some of the recommended therapies for different conditions found in the textbooks and professional literature are reified as practice guidelines by various organizations and the government. Some recommended therapies have demonstrated their effectiveness in randomized controlled trials, whereas others, both old and new, have much less scientific support.

Treatment options for an individual patient must be assessed in light of the nature and severity of the particular disease (e.g., people whose lung cancer is metastatic are not often candidates for removal of the primary tumor), and the likelihood of unacceptable complications from the treatment (e.g., removal of a lung to cure cancer in someone with severe emphysema may not leave enough remaining lung tissue to allow the patient to walk, even if his or her cancer is cured).¹⁴⁵ Prediction of the effects, both positive and negative, of a course of therapy is based on the professional literature and consideration of a patient's specific situation. For example, a patient with underlying kidney disease may not be an appropriate candidate for some radiographic tests and therapies that use dye that runs a high risk of causing further damage to the kidneys. Use of an effective antibiotic to which a patient "may possibly" have had a previous aller-

144. See Kassirer & Kopelman, *supra* note 48, at 11, 32–33.

145. A physician's selection of appropriate treatment is often at issue in medical malpractice cases (see *supra* notes 31–32 and accompanying text), but it also is at issue in other kinds of cases, including claims that medical treatment was "necessary" and therefore covered in insurance litigation under ERISA (see, e.g., McGraw v. Prudential Ins. Co., 137 F.3d 1253, 1258–1263 (10th Cir. 1998)), claims that treatment was improperly withheld from prisoners under the Eighth Amendment (see, e.g., Kulas v. Roberson, 202 F.3d 278 (9th Cir. 1999) (unpublished table decision) (text at No. 98-16954, 1999 WL 1054663 (9th Cir. Nov. 19, 1999) (mem.)), and medical monitoring claims (see, e.g., *In re Paoli R.R. Yard PCB Litig.*, 916 F.2d 829, 852 (3d Cir. 1990), *cert. denied*, 499 U.S. 961 (1991)).

gic reaction should be weighed against the use of alternative antibiotics that may be less effective against the infection. The physician may also consider the likely severity of a reaction and the ability to prevent or treat it with additional medication. Thus, although treatment recommendations are often written down as a precise series of sequential decisions (often called algorithms), making decisions for actual patients is generally more complex and requires consideration of many individual factors.

VI. Medical Testimony: Looking to the Future

It is likely that medical testimony will continue to be one of the most common forms of expert testimony in the future. While many commentators have focused attention on medical testimony in toxic injury cases, particularly testimony offered on issues of external causation, a growing number of cases concern ERISA suits challenging coverage under health care plans and claims of unlawful discrimination under the Americans with Disabilities Act. As the health care system continues to evolve, there will be growing numbers of cases, particularly on coverage issues, requiring medical testimony. Also, advances in the medical sciences, including medical genetics and biotechnology, will present new challenges to courts in cases requiring medical testimony.

With this forecast, courts will continue to grapple with issues of admissibility of medical testimony for the foreseeable future. As the cases we have used to illustrate this chapter demonstrate, there are great and unresolved differences in how various courts treat the admissibility of medical testimony. While this reference guide does not propose legal standards to govern admissibility of medical evidence,¹⁴⁶ it does provide a framework for legal analysis by describing the scientific and professional practices of physicians as they perform their professional duties and offer opinions on diagnosis, treatment, and internal and external causation. It is challenging to encourage consistent use of medical terminology and make explicit the extensive knowledge base and reasoning process that physicians implicitly employ in evaluating medical problems. Further work in these areas will improve the transferability of medical knowledge into the courts and other arenas.

146. *See supra* note 30.

Glossary of Terms

- adequacy of diagnostic hypothesis.** Diagnostic sufficiency. To be considered adequate, a diagnostic hypothesis must explain the patient's normal findings as well as abnormal findings.
- attending physician.** A physician formally attached to (credentialed at) the hospital in which the patient is being treated.
- Bayes' theorem.** An algebraic formula that allows the pretest and posttest clinical data to be expressed in terms of probabilities. By integrating the pretest probability of a disease or set of diseases with the result of a given test (and taking into account the sensitivity and specificity of that test), the physician is able to calculate a posttest probability of a disease or set of diseases. This approach can be useful in certain circumstances, but many clinical situations can be so complex that it is impractical to apply Bayes' theorem.
- case report/case series.** The most basic type of descriptive study of an individual (case report) or a series of individuals (case series), usually including such factors as gender, age, and exposure or treatment, but without controlled assessment of the relationship between exposure or treatment and disease or outcome.
- clinical tests.** Noninvasive tests of the function of an organ system, including tests of pulmonary function, muscle function, endurance, and heart function.
- coherency of a diagnostic hypothesis.** In a coherent diagnostic hypothesis, the patient's findings (signs, symptoms, test results), risk factors, and complications match the expectations for the disease.
- consulting physician.** A physician brought in to give an expert opinion or a second opinion, who may or may not be involved in treatment. He or she may rely on information contained in the patient's medical records, patient history, laboratory tests, x-rays, and so forth, or may combine these facts with his or her own examination of the patient and any additional tests considered advisable.
- diagnosis.** The determination of which disease is most likely present in a given patient, as indicated by the patient's various symptoms, signs, and test results.
- diagnostic hypothesis.** One or more disease entities, conditions, or syndromes postulated to be responsible for causing a patient's clinical presentation. See working diagnosis.
- diagnostic tests.** Any tests (clinical, laboratory, or pathologic) whose results may assist the physician in making his or her diagnosis.

differential diagnosis. The term used by physicians to refer to the process of determining which of two or more diseases with similar symptoms and signs the patient is suffering from, by means of comparing the various competing diagnostic hypotheses with the clinical findings.

differential etiology. A term used on occasion by expert witnesses or courts to describe the investigation and reasoning that leads to a determination of external causation, sometimes more specifically described by the witness or court as a process of identifying external causes by a process of elimination.

disease. Coherent deviation from normal in structure or function that affects a certain part or parts of the body or type of tissue.

dose-response relationship. The general tendency to observe greater responses in individuals when they are given greater doses of a drug or toxic substance. The presence of such a relationship supports an inference of a causal relationship between exposure and response (disease).

external causation. As used herein, an underlying cause of a given disease in a given individual that stems from a source outside the individual's body. A hereditary disease such as Tay-Sachs disease or hemophilia would not be due to external causation; cirrhosis of the liver resulting from excessive alcohol intake or ataxia resulting from lead poisoning would be due to external causation.

general causation. General causation is established by demonstrating (usually by reference to a scientific publication) that exposure to the substance in question causes (or is capable of causing) disease; for example, smoking cigarettes causes lung cancer.

inductive reasoning. See inferential reasoning.

inferential reasoning. The reasoning process by which a physician assimilates the various findings on a given patient and forms hypotheses that lead to testing and further hypotheses until a coherent diagnosis is reached.

invasive procedure. A procedure (surgery, test, etc.) in which the body of the patient is invaded by an instrument of some sort. Invasive procedures may be as minimal as the biopsy of a lesion on the skin or as traumatic as open-heart surgery.

laboratory tests. Analyses of fluids or other substances collected from the body of the patient, including blood samples, urine samples, and fecal samples.

multiplicative interaction. A process that occurs when two toxic agents (or two disease states) interact in the patient in such a manner that the magnitude of their combined effects is equal to the product of the effect of each agent (or disease) working in isolation. This is a special instance of synergism.

- noninvasive procedure.** A procedure (usually a test procedure) that does not invade the body of the patient, including exercise and stress tests, electrocardiograms, CAT scans, and MRIs.
- parsimony in a diagnostic hypothesis.** A preference for the simplest way to coherently and adequately explain all of the patient's findings, normal and abnormal.
- pathogenesis.** The mode of origin or development of any disease or morbid process.
- pathology test.** Microscopic analysis of a piece of body tissue obtained during surgery or by biopsy, in which an expert determines whether the tissue appears to be normal for the organ from which it was taken. If it does not appear normal, the expert then attempts to determine what the pattern of abnormality is (scarring, malignancy, inflammation, etc.)
- pathophysiology.** The derangement of function seen in disease; alteration in function as distinguished from structural disease.
- patient history.** An interview conducted by the treating physician with the patient, in which the physician elicits from the patient the symptoms he or she is suffering from, as well as information about past and present medical history and treatment, personal information on family status and lifestyle, environmental information about habitation and employment, and the like.
- physical exam.** A noninvasive, largely external examination of the patient's body in which the physician looks for signs of normal and abnormal function. The physician may do a physical examination of a healthy individual to fulfill the requirements of an employer or insurance company, or of a patient who is ill to substantiate or refute the symptoms obtained from a patient during the taking of the patient history.
- predictive value.** The extent to which a given test will predict the presence or absence of a given disease. The positive predictive value of a test or observation refers to the proportion of all positive results that are "true" positive test results in a particular population. The negative predictive value of a test or observation refers to the proportion of "true" negative results in a population.
- sensitivity.** The percentage of patients with positive test results for a disease who actually have the disease (called a "true positive" result). Test results for those who have a disease but are incorrectly identified as not having the disease because of the test's insensitivity are called "false negatives." A test with high sensitivity given to people suffering from the disease it tests for will have a high proportion of true positives and only a few false negatives. A test with low sensitivity will reveal a considerable number of false negatives and fewer true positives.

- sensitization.** The initial exposure of a person to a specific antigen (any substance that is capable of inducing an immune reaction in an individual and of reacting with the products of that response); repeated exposure to the same antigen may then result in a much stronger immune response (e.g., an individual stung by a bee on one occasion may have a stronger response if stung again, and if subjected to sufficient numbers of bee stings, may eventually react by going into anaphylactic shock).
- sign.** A physical condition observed in a patient by the physician in the course of a physical examination, such as fever, cardiac murmur, enlarged lymph nodes, suspicious breast mass.
- specific causation.** Specific, or individual, causation is established by demonstrating that a given exposure is the cause of an individual's disease (for example, that a given plaintiff's lung cancer was caused by smoking).
- specificity.** The percentage of negative test results in individuals who are free of a given disease, also known as the "true negative" rate. Test results in those who are free of the disease who are incorrectly identified as having the condition are called "false positives." Thus, a test that indicates abnormal bronchial reactivity in 15% of individuals without asthma would have a false positive rate of 15%; their test results were positive, but they are free of the condition.
- susceptibility.** The propensity of an individual to be harmed by an agent (e.g., a person who has a high susceptibility to irritant gases will suffer from bronchitis or asthma more than a person with a low susceptibility). Susceptibility tends to be influenced by age, gender, and genetics as well as the individual's state of health and history of prior exposure.
- symptom.** A patient's subjective report of physical abnormality as described to the physician during the taking of the patient history. Symptoms may include reports of pain in various parts of the body, sensations such as dizziness or fatigue, fever or chills, or swelling or suspicious nodules. If a symptom, such as fever or the existence of a suspicious breast nodule, is verified by the physician during the physical exam, it is considered a sign.
- syndrome.** A clustering of the symptoms, signs, and laboratory findings that indicate a specific disease state.
- synergistic interaction.** The joint action of two or more agents such that their combined effect is greater than the sum of the effects of each agent working separately. See multiplicative interaction.
- threshold.** The lowest dose of any substance at which a measurable response occurs. For a substance that produces more than one effect, the threshold may vary according to the effect. For instance, with a neurotoxin that can

produce dizziness, convulsion, coma, and death, the thresholds for the different effects can vary from quite low for dizziness to relatively high for death.

treating physician. A physician in charge of diagnosis and therapy for a given patient. The treating physician is likely to be an attending physician at the hospital to which the patient has been admitted. Many physicians will act as treating physicians with patients for whom they provide primary care, but may be called upon to act as consulting physicians at the request of colleagues or the patients of other physicians.

working diagnosis. A diagnostic hypothesis sufficiently convincing to form the basis for planning the next step in patient management. A working diagnosis may provide a rationale for the physician to order further tests, to forecast a likely clinical course for the patient, to refrain from further testing and simply to observe the patient for a given time, or to initiate a course of treatment. If a working diagnosis proves to be correct, either by subsequent testing or by patient response, it may become the final diagnosis.

References on Medical Testimony

- Thomas E. Andreoli et al., *Cecil Essentials of Medicine* (3d ed. 1993).
- Barbara Bates et al., *A Guide to Physical Examination and History Taking* (6th ed. 1995).
- Joan E. Bertin & Mary S. Henifin, *Science, Law, and the Search for the Truth in the Courtroom*, 22 J.L. Med. & Ethics 6 (1994).
- Environmental Medicine* (Stuart M. Brooks et al. eds., 1995).
- 1 & 2 *Harrison's Principles of Internal Medicine* (Anthony S. Fauci et al. eds., 14th ed. 1998).
- Alvan R. Feinstein, *Clinical Judgment* (1967).
- Michael D. Green, *Bendectin and Birth Defects: The Challenges of Mass Toxic Substances Litigation* (1996).
- Jerome P. Kassirer & Richard I. Kopelman, *Learning Clinical Reasoning* (1991).
- Susan R. Poulter, *Medical and Scientific Evidence of Causation: Guidelines for Evaluating Medical Opinion Evidence*, in *Expert Witnessing: Explaining and Understanding Science* 186 (Carl Meyer ed., 1999).
- Susan R. Poulter, *Science and Toxic Torts: Is There a Rational Solution to the Problem of Causation?* 7 High Tech. L.J. 189 (1992).