

22 P.3d 68 (Colo. 2001)
IN RE: Plaintiff: THE PEOPLE OF THE STATE OF COLORADO,
v.
Defendant: MICHAEL EUGENE SHRECK.
Case No. 00SA105
SUPREME COURT, STATE OF COLORADO
April 23, 2001

Original Proceeding Pursuant to C.A.R. 21
Boulder County District Court, No. 98CR2475
Honorable Daniel C. Hale, Judge
Ann B. Tomsic, Special Prosecutor, Arapahoe County District, Attorney's Office, Englewood, Colorado,
Attorney for Plaintiff
David Kaplan, Colorado State Public Defender, Steven K. Jacobson, Deputy State Public Defender, Kristin
Johnson, Deputy State Public Defender, Boulder, Colorado, Attorneys for Defendant
Ken Salazar, Attorney General, Deborah Isenberg Pratt, Assistant Attorney General, Denver, Colorado
Attorneys for Amicus Curiae in Support of Plaintiff
RULE MADE ABSOLUTE
EN BANC

JUSTICE RICE delivered the Opinion of the Court.

The prosecution in this case initiated this original proceeding pursuant to C.A.R. 21, seeking relief from a trial court order granting the defendant's motion to bar DNA evidence. The trial court held that under *Frye v. United States*, 293 F. 1013, 1014 (D.C. Cir. 1923), the multiplex technique employed by the commercial testing kits used by the Colorado Bureau of Investigation ("CBI") in 1999 was not yet generally accepted at that time by the relevant scientific community. Thus, the trial court ruled that the DNA evidence at issue in this case, which was derived from those kits, was not admissible against the defendant. We issued a rule to show cause why the trial court's order should not be vacated, and the defendant responded.

We now hold that CRE 702, rather than *Frye*, governs a trial court's determination as to whether scientific or other expert testimony should be admitted. Such an inquiry should focus on the reliability and relevance of the proffered evidence and requires a determination as to (1) the reliability of the scientific principles, (2) the qualifications of the witness, and (3) the usefulness of the testimony to the jury. We also hold that when a trial court applies CRE 702 to determine the reliability of scientific evidence, its inquiry should be broad in nature and consider the totality of the circumstances of each specific case. In doing so, a trial court may consider a wide range of factors pertinent to the case at bar. The factors mentioned in *Daubert v. Merrell Dow Pharmaceuticals, Inc.*, 509 U.S. 579, 593-94 (1993), and by other courts may or may not be pertinent, and thus are not necessary to every CRE 702 inquiry. In light of this liberal inquiry, a trial court should also apply its discretionary authority under CRE 403 to ensure that the probative value of the evidence is not substantially outweighed by unfair prejudice. Finally, we hold that under CRE 702, a trial court must issue specific findings as it applies the CRE 702 and 403 analyses.

We further hold that under CRE 702, the multiplex testing techniques at issue in this case were sufficiently reliable to warrant admission of the DNA evidence derived from their use. Accordingly, we make the rule absolute and direct the trial court to vacate its order barring such evidence.

I. SCIENTIFIC BACKGROUND

We described the scientific principles and techniques underlying DNA typing in *Fishback v. People*, 851 P.2d 884, 885 (Colo. 1993). We now review those principles and techniques in the context of the particular method of DNA typing at issue in this case.

Within the nucleus of each human cell are twenty-three pairs of chromosomes composed of deoxyribonucleic acid ("DNA"), which contains the coded information that provides the genetic material determining the physical structure and characteristics for each individual. No two individuals, except identical twins, have the same DNA structure. A DNA molecule is shaped like a double helix, which resembles a twisted ladder. The sides of the ladder are composed of phosphate and sugar molecules and the rungs are composed of a pair of organic compounds called bases. Two bases form a single rung called a base pair. The order in which these base pairs appear in the ladder is the genetic code of that individual. There are approximately three billion base pairs in a human being, 99% of which are the same in each person. However, certain sections of DNA vary from person to person. These areas are called polymorphisms. DNA typing concerns the examination of two types of polymorphisms: length and sequence.

One method of detecting and measuring length variations is called restriction fragment length polymorphism ("RFLP") analysis. The RFLP procedure isolates DNA in a blood sample so that certain polymorphisms can be located in the DNA. RFLP is a widely accepted and scientifically validated method of testing that has generally been found to be admissible in state and federal courts. *United States v. Hicks*, 103 F.3d 837, 846-47 (9th Cir. 1996); *United States v. Chischilly*, 30 F.3d 1144, 1153-56 (9th Cir. 1994); *United States v. Lowe*, 954 F. Supp. 401, 416 (D. Mass. 1996); *Fishback*, 851 P.2d at 893.

Polymerase chain reaction ("PCR") is a process by which DNA fragments too small to be suitable for RFLP analysis can be analyzed. Under the PCR process, these DNA fragments are duplicated many times, thus allowing very small samples to be accurately tested. PCR also permits testing in a relatively short time in comparison to prior methods that required the decay of radioactive materials. Finally, unlike RFLP testing, which destroys the sample, PCR processing allows a technician to reproduce and verify test results by creating a larger sample for testing.

The D1S80 test is a hybrid of the PCR and RFLP methods. It detects fragment length polymorphisms once the DNA fragment has been amplified through the PCR procedure.

Another form of PCR testing involves the use of locations on the DNA strand containing short tandem repeats ("STR") of baseline patterns. STR testing reveals length differences between chromosomes on different people with the same base pair sequences. There are thirteen locations at which the number of STRs are known to vary from person to person. Thus, if all thirteen locations of the known and questioned sample are identical, a match is considered to have been made.

When STR loci are amplified through the PCR process separately and run on a separate gel, the system is called "monoplex." Multiplex systems add more than one set of PCR primers to a reaction so as to be able to amplify several loci together and run them simultaneously. Monoplex systems and multiplex systems that amplify and run three loci simultaneously, ("triplex"), have been in use for many years.

The commercial kits used to perform the STR testing at issue in this case were manufactured by Perkins Elmer Biosystems ("PE"). These kits, called AmpFLSTR Profiler Plus ("Profiler Plus") and AmpFLSTR Cofiler ("Cofiler"), employ a combination sixplex and nineplex system that is able to read all thirteen locations at the same time.¹ In January 1999, when they were used in this case, the kits were relatively new to the market.

II. FACTS AND PROCEDURAL HISTORY

The defendant in this case has been in and out of jail since 1983. In April 1990, he was on parole and living in the Boulder area when a University of Colorado student was sexually assaulted. Although a rape kit was used on the victim, the crime was never solved. In 1998, the case was reopened and the CBI performed a DNA analysis using several PCR-based tests on the rape kit samples. A 1991 blood sample from the defendant was analyzed against the rape kit results. The CBI concluded that the probability that the contributor to the rape kit sample was not the defendant was one in 11,000. An analysis of a new blood sample from the defendant revealed identical results.

Several months later, the CBI performed more tests on the samples, this time using the Profiler Plus and Cofiler kits. By combining the Profiler Plus and Cofiler results with the earlier tests, the CBI determined that the defendant could not be excluded as a contributor to the rape kit sample. The CBI also determined that the probability that the contributor was not the defendant but a random third person was one in 5.3 quadrillion.² Based on the DNA results, a positive photo line-up identification by the victim, and the fact that the defendant had been on parole and living in the area at the time of the crime, the defendant was arrested and charged with second degree kidnapping, two counts of sexual assault in the first degree, two counts of criminal attempt to commit murder in the first degree, assault in the second degree, and as a habitual criminal.

The defendant moved to bar the use of the DNA evidence at trial on the grounds that (1) PCR and the PCR-based tests employed in this case were not generally accepted as reliable by the relevant scientific community; (2) STR tests in general and the STR multiplex technique employed by the Profiler Plus and Cofiler kits were not generally accepted; and (3) the methods of collection, preservation and handling of the samples, and the statistical methods used to determine the probability of a match were not generally accepted.

Applying the Frye standard as adopted in Colorado by *People v. Anderson*, 637 P.2d 354, 358 (Colo. 1981), and as explained in *People v. Lindsey*, 892 P.2d 281, 288-89 (Colo. 1995), and *Fishback v. People*, 851 P.2d 884, 890 (Colo. 1993), the trial court held that admissibility of the DNA evidence at issue required a showing that the technologies and methods used were generally accepted in the relevant scientific community. After reviewing the evidence, rulings from other jurisdictions, and scientific commentary and journals, the trial court concluded that PCR and the PCR-based tests used in this case, as well as the handling and statistical methods used, were generally accepted in the scientific community. The court also concluded that although PCR-based STR testing is different from other PCR-based tests, it is generally accepted as to monoplex and triplex applications.

The court, however, ruled that because the multiplex system at issue in this case involves a combination nineplex and sixplex system using new loci and primers, it differs from previous STR tests in a critical way, thus triggering a new Frye analysis. The trial court determined that the evidence of validation and peer review offered by the prosecution failed to meet guidelines published by the Technical Working Group on DNA Analysis Methods ("TWGDAM"). Thus, the court concluded that the multiplex technique employed by the Profiler Plus and Cofiler systems is not generally accepted and that the DNA evidence resulting from its use is therefore inadmissible. Alternatively, the trial court concluded under Daubert, that the Profiler Plus and Cofiler systems were not sufficiently reliable under CRE 702 to warrant admission of the DNA evidence derived from their use.

The prosecution petitioned for a writ in the nature of prohibition pursuant to C.A.R. 21. We issued a rule to show cause why the trial court's order should not be vacated, and the defendant responded. We now hold that CRE 702 governs a trial court's determination as to whether scientific evidence should be admitted. Under CRE 702, we hold that the multiplex STR testing techniques at issue in this case are sufficiently reliable and relevant to warrant admission. Accordingly, we make the rule absolute and direct the trial court to vacate its order barring the DNA evidence derived from these tests.

III. ANALYSIS

We have not previously addressed the admissibility of PCR or STR-based DNA testing, or the specific multiplex testing systems at issue here. Thus, this case presents us with the opportunity to address these matters of first impression. In doing so, we consider the appropriate standard governing the admissibility of scientific evidence. Our review includes an analysis of relevant Colorado case law, similar cases in other jurisdictions, and academic commentary.

A. Standard of Review

Under C.A.R. 21, we may, in our discretion, grant relief when (1) the trial court is proceeding without or in excess of its jurisdiction, or (2) it has abused its discretion, and (3) when no other adequate remedy exists. C.A.R. 21; *People v. District Court*, 898 P.2d 1058, 1060 (Colo. 1995). In this case, the prosecution's ability to present its case has been impaired by the exclusion of the DNA evidence in question. *Id.* Because double jeopardy would bar a retrial if the defendant were acquitted, no other adequate remedy exists. *People v. District Court*, 664 P.2d 247, 251 (Colo. 1983). As discussed below, we hold that the trial court erred in finding that the DNA evidence derived from the multiplex STR systems at issue in this case was inadmissible, and that its exclusion of the evidence was an abuse of discretion. Thus, relief under C.A.R. 21 is appropriate here.

B. Admissibility of Scientific Evidence Generally

Prior to 1993, the widely accepted standard for admitting novel scientific evidence in both federal and state courts was the standard articulated in *Frye*. *Daubert*, 509 U.S. at 585 (noting that, "In the 70 years since its formulation in the *Frye* case, the 'general acceptance' test has been the dominant standard for determining the admissibility of novel scientific evidence at trial."). This standard requires that "the thing from which [expert testimony is deduced] be sufficiently established to have gained general acceptance in the particular field to which it belongs." *Frye*, 293 F. at 1014. Applying this standard, the *Frye* court concluded that the systolic blood pressure deception test had not yet gained enough recognition among scientific authorities to warrant admission of its results. *Id.*

Most courts have interpreted *Frye* as requiring general acceptance of both (1) the underlying theory supporting the scientific conclusion and, (2) the techniques and experiments employing that theory.³ The court in *People v. Castro*, 545 N.Y.S.2d 985, 986 (N.Y. Sup. Ct. 1989), however, held that a third requirement should apply in the complex area of DNA identification: that the actual testing procedures employed properly apply the accepted scientific techniques in analyzing the forensic samples at issue. Other courts have held that questions concerning testing procedures and the accuracy of particular test results go to the weight, rather than admissibility of the evidence. See, e.g., *Chischilly*, 30 F.3d at 1154; *United States v. Bonds*, 12 F.3d 540, 563 (6th Cir. 1993); *United States v. Shea*, 957 F. Supp. 331, 341 (D.N.H. 1997), *aff'd*, 159 F.3d 37 (1st Cir. 1998).

In 1993, the United States Supreme Court held in *Daubert v. Merrell Dow Pharmaceuticals, Inc.* that *Frye*'s general acceptance test had been superseded by the adoption of Federal Rule of Evidence 702.⁴ 509 U.S. at 587. The Court reasoned that *Frye*'s "rigid general acceptance requirement is at odds with the liberal thrust of the Federal Rules and their general approach of relaxing the traditional barriers to opinion testimony." *Id.* at 588. The *Daubert* Court held that admissibility of scientific evidence under the Federal Rules of Evidence requires that the trial judge ensure that the evidence be both relevant and reliable. *Id.* at 589. The Court thus held that under Rule 702, the reasoning or methodology underlying the testimony must be scientifically valid, and that such reasoning or methodology may properly be applied to the facts of the case. *Id.* at 592. The Court then set forth a non-exclusive

list of factors, including general acceptance, to guide a trial court in making this determination. *Id.* at 593-94. The Court concluded its analysis by noting that the "inquiry envisioned by Rule 702 is . . . a flexible one," and that the focus of the inquiry should be scientific validity as it pertains to evidentiary relevance and reliability. *Id.* at 594.

Recently, the United States Supreme Court expanded *Daubert's* general holding concerning the trial judge's gatekeeping function to testimony based not only on scientific knowledge, but also to testimony based on technical and "other specialized" knowledge. *Kumho Tire Co. v. Carmichael*, 526 U.S. 137, 142 (1999). The Court stressed, however, that the inquiry was a flexible one, and held that the factors listed in *Daubert* were neither exclusive nor mandatory. *Id.*

C. Admissibility of Scientific Evidence in Colorado

Before reaching the relative merits of *Frye* and Rule 702 for determining the admissibility of scientific evidence, we review our previous treatment of these standards in Colorado. The *Frye* standard was first adopted in Colorado in *People v. Anderson*, 637 P.2d at 358. In *Anderson*, this court held that polygraph results and the testimony of polygraph examiners were per se inadmissible in a criminal trial because the scientific theory or technique of the polygraph was not sufficiently advanced to permit its use at trial as competent evidence of credibility. *Id.*

We limited the applicability of *Frye*, however, in *People v. Hampton*, 746 P.2d 947, 951 (Colo. 1987), where we applied CRE 702, rather than *Frye*, to determine the admissibility of rape trauma syndrome evidence. There, we reasoned that *Frye* was only applicable to novel scientific devices and processes involving the manipulation of physical evidence, and that *Frye* had only been applied in Colorado to polygraph tests. *Id.* at 950-51. Thus, we held that CRE 702, rather than *Frye*, governed the admission of testimony regarding rape trauma syndrome. *Id.*

Similarly, in *Campbell v. People*, 814 P.2d 1, 7 (Colo. 1991), we applied CRE 702, rather than *Frye*, in determining whether eyewitness identification evidence should be admitted. In that case, we explicitly held that *Frye* was only applicable to cases involving novel scientific devices or processes involving the evaluation of physical evidence. *Id.* at 8. Because no such scientific device or process was at issue in *Campbell*, we held that CRE 702's more liberal standard for admissibility should have been applied to the eyewitness identification evidence. *Id.*

We first addressed the admissibility of DNA evidence in Colorado in *Fishback v. People*, where we held that DNA evidence, unlike the evidence at issue in *Hampton* and *Campbell*, is "precisely the sort of scientific evidence which requires application of the *Frye* test." 851 P.2d at 890. In concluding that the *Frye* test governed our inquiry, we reasoned that the highly technical and sophisticated techniques involved in DNA typing, and its relative novelty at the time, qualified it as "a novel scientific process involving the evaluation of physical evidence." *Id.* We also held that general acceptance of both the underlying theory or principle, and of the techniques used to apply that principle was required under *Frye*. *Id.* at 891. Applying this standard, we concluded that the theory underlying DNA typing, the techniques employed in RFLP analysis, and the statistical techniques employed in that case were generally accepted among the relevant scientific communities. *Id.* at 892-93.

In *Lindsey v. People*, we again considered the admissibility of DNA evidence in Colorado courts. 892 P.2d at 281. At issue in that case was the statistical method used to analyze DNA results. *Id.* at 285. Although we acknowledged that the United States Supreme Court had abandoned *Frye's* general acceptance test in *Daubert*, we concluded that we were not bound by *Daubert's* non-constitutional construction of the Federal Rules of Evidence. *Id.* at 288. Thus, we applied *Frye*, as interpreted in *Fishback*, to hold that the DNA statistical frequency analysis employed in that case was generally accepted. *Id.* at 288-95. In doing so, we noted that general acceptance could be considered broadly to mean accepted in a reasonably inclusive manner, and including a consideration of rulings from other jurisdictions and the general state of science. *Id.* at 289. We expressly declined, however, to evaluate the relative merits of *Frye* and CRE 702 in determining the admissibility of scientific evidence, noting that the issue was not before us in that case. *Id.* at 288.

In *Brooks v. People*, 975 P.2d 1105, 1106 (Colo. 1999), we declined to apply either *Frye* or *Daubert* to the determination as to whether testimony on the subject of scent tracking evidence was admissible. In doing so, we reasoned that the evidence in question did not involve the type of scientific devices, processes, or theories that are properly subject to *Frye* scrutiny. *Id.* at 1111-12. We were also unwilling to apply *Daubert* for the first time in that case, because we found that the scent-tracking evidence was experience-based specialized knowledge that was not dependent on scientific explanation, remarking that *Daubert* itself limited its holding to the scientific realm. *Id.* at 1113; see *Daubert*, 509 U.S. at 590 n.8. We noted that the decision in *Kumho* applied *Daubert* to technical and other specialized knowledge and that it provided that the *Daubert* factors were not exclusive. However, we opined that it was preferable to avoid debating whether or to what extent *Daubert* was applicable and held instead that CRE 702

and CRE 403 governed our determination as to whether the experience-based knowledge at issue in that case was admissible. Brooks, 975 P.2d at 1115.

A review of our previous treatment of Frye indicates that we have not fully endorsed its general acceptance standard as the appropriate test for determining the admissibility of scientific evidence in Colorado. After initially adopting Frye in the context of Anderson, which, like Frye, concerned the admissibility of polygraph evidence, we later limited its applicability in Hampton, 746 P.2d at 951, and in Campbell, 814 P.2d at 7, to novel scientific devices or processes involving the evaluation of physical evidence.

Although we later applied Frye in both Fishback and Lindsey to determine the admissibility of DNA evidence, we did so without evaluating the relative merits of Frye and CRE 702.5 In Brooks, we applied the rules of evidence, specifically Rules 702 and 403, rather than Daubert or Frye to determine the admissibility of experience-based scent-tracking evidence. 975 P.2d at 1106.

In order to determine whether the DNA evidence derived from the multiplex STR technique at issue here was properly barred, we must first address the proper standard governing the admissibility of scientific evidence in Colorado. Because we have never addressed the relative merits of Frye and CRE 702, we now undertake that analysis in an effort to clearly set forth the standard for admitting scientific evidence in Colorado.⁶

Proponents of Frye's general acceptance test argue that it insulates juries from unreliable evidence that has not yet been found reliable by a sufficient number of experts. Joseph G. Petrosinelli, Note, The Admissibility of DNA Typing: A New Methodology, 79 Geo. L.J. 313, 317 (1990). Another justification for the Frye test is that it provides a method by which courts can assess the reliability of novel scientific expert testimony. United States v. Downing, 753 F.2d 1224, 1235 (3d Cir. 1985). Finally, proponents of Frye also argue that the general acceptance test safeguards against the possible prejudicial effects of testimony based upon questionable scientific evidence. Id.

Frye's general acceptance test has also, however, been heavily criticized on several grounds. Lawrence B. Ebert, Frye after Daubert: The Role of Scientists in Admissibility Issues as Seen through Analysis of the DNA Profiling Cases, The University of Chicago Law School Roundtable, 219 (1993); Petrosinelli, supra, at 318; Paul C. Giannelli, The Admissibility of Novel Scientific Evidence: Frye v. United States, a Half-Century Later, 80 Colum. L. Rev. 1197, 1208-23 (1980). Generally, critics have been concerned with Frye's vagueness and its conservatism. Downing, 753 F.2d at 1236.

Commentators have found vagueness and ambiguity under Frye in determining, for example, (1) precisely what must be generally accepted, (2) the relevant scientific community, (3) how much agreement constitutes general acceptance, and (4) the extent to which Frye applies. Ebert, supra, at 225; Petrosinelli, supra, at 320; Giannelli, supra, at 1208-23. Such ambiguity yields inconsistent results and creates uncertainty in decision-making. Fishback, 851 P.2d at 896-97 (Mullarkey, J., concurring in the result only).⁷

Furthermore, while some critics have argued that the Frye inquiry is too malleable,⁸ others have concluded that the Frye standard is too rigid and that it unduly restricts the admission of probative evidence from a jury's consideration. See, e.g., Downing, 753 F.2d at 1236-37 (noting that some have argued that under Frye, courts may be required to exclude much probative and reliable information from the jury's consideration, thereby unnecessarily impeding the truth-seeking function of litigation); United States v. Sample, 378 F. Supp. 44, 53 (E.D. Pa. 1974) (noting that general acceptance is a proper requirement for taking judicial notice of scientific facts, but should not be a criterion for the admissibility of scientific evidence); People v. Leahy, 882 P.2d 321, 330 (Cal. 1994) (acknowledging that a reliable, readily provable technique could remain unknown and untested by the relevant scientific community, thus delaying its use in the courtroom). We agree that Frye's rigidity may exclude evidence with strong support within the community but that may fall short of "general acceptance" under Frye. Fishback, 851 P.2d at 897 (Mullarkey, J., concurring in the result only); Lindsey, 892 P.2d at 296 (Mullarkey, J., concurring in the result only).

We also find that this rigidity is ill-suited for determining the admissibility of scientific evidence, which, by its nature, is ever-evolving. Under Frye, once a scientific principle or discovery becomes generally accepted, it forever remains accepted, despite improvements or other developments in scientific technologies. Fishback, 851 P.2d at 897 (Mullarkey, J., concurring in the result only); Lindsey, 892 P.2d at 296 (Mullarkey, J., concurring in the result only). Conversely, because it will take time for any scientific technique to become generally accepted, the Frye test restricts the admissibility of reliable evidence that may not yet qualify as "generally accepted" under Frye. Brooks, 975 P.2d at 1112 (noting that Frye fails to "address the tough questions that arise on the cutting edge of science, [in that it] requires that the courts wait until science itself determines the validity of the scientific proposition in question."); Downing, 753 F.2d at 1236-37; Petrosinelli, supra, at 320 (describing this problem with the Frye test as

a "cultural lag"). Thus, we conclude that Frye's general acceptance test, particularly when viewed rigidly, is unsuitable as the sole dispositive standard for determining the admissibility of scientific evidence in Colorado.⁹

We therefore hold that the rules of evidence, particularly CRE 70210 and CRE 403, represent a better standard, because their flexibility is consistent with a liberal approach that considers a wide range of issues. See *Downing*, 753 F.2d at 1237 (noting that the language of Rule 702, the spirit of the rules of evidence, and the problems with applying Frye "suggest the appropriateness of a more flexible approach to the admissibility of . . . scientific evidence").

The focus of a Rule 702 inquiry is whether the scientific evidence proffered is both reliable and relevant. *Daubert*, 509 U.S. at 589; see *Brooks*, 975 P.2d at 1114 (holding that under CRE 702, evidence that is reasonably reliable and that will assist the trier of fact should be admitted). In determining whether the evidence is reliable, a trial court should consider (1) whether the scientific principles as to which the witness is testifying are reasonably reliable, and (2) whether the witness is qualified to opine on such matters. *Brooks*, 975 P.2d at 1114. In determining whether the evidence is relevant, a trial court should consider whether the testimony would be useful to the jury. *Id.*

A trial court's reliability inquiry under CRE 702 should be broad in nature and consider the totality of the circumstances of each specific case. *Brooks*, 975 P.2d at 1114 (noting that "the relevant factors applicable to a CRE 702 inquiry will likely vary depending on the particular subject matter at hand"); *Campbell*, 814 P.2d at 7-8 (holding that the trial court retains its broad discretion to evaluate on a case-by-case basis whether the testimony in question would assist the trier of fact to understand the evidence or to determine a fact in issue); see also *Kumho*, 526 U.S. at 150 (holding that a trial court's gatekeeping inquiry under Rule 702 must be tied to the facts of a particular case).

Given the flexible, fact-specific nature of the inquiry, we decline to mandate that a trial court consider any particular set of factors when making its determination of reliability. Instead, we hold that the CRE 702 inquiry contemplates a wide range of considerations that may be pertinent to the evidence at issue. *Downing*, 753 F.2d at 1238 ("The reliability inquiry that we envision is flexible and may turn on a number of considerations, in contrast to the process of 'nose-counting' that would appear to be compelled by a careful reading of Frye.").

By way of illustration, however, we recite here the wide range of issues other courts have considered when making a Rule 702 determination. For example, in *Daubert*, the Court articulated the following nonexclusive list of general observations that a trial court might consider: (1) whether the technique can and has been tested; (2) whether the theory or technique has been subjected to peer review and publication; (3) the scientific technique's known or potential rate of error, and the existence and maintenance of standards controlling the technique's operation; and (4) whether the technique has been generally accepted. 509 U.S. at 593-94. The Third Circuit has articulated yet other considerations: (1) the relationship of the proffered technique to more established modes of scientific analysis; (2) the existence of specialized literature dealing with the technique; (3) the non-judicial uses to which the technique are put; (4) the frequency and type of error generated by the technique; and (5) whether such evidence has been offered in previous cases to support or dispute the merits of a particular scientific procedure. *Downing*, 753 F.2d at 1238-39.

We hold that a trial court making a CRE 702 reliability determination may, but need not consider any or all of these factors, depending on the totality of the circumstances of a given case. A trial court may also consider other factors not listed here, to the extent that it finds them helpful in determining the reliability of the proffered evidence.

Our determination that a trial court may, but need not consider the factors listed in *Daubert* is consistent with the United States Supreme Court's reasoning in *Kumho Tire Co. v. Carmichael*: "[T]he factors identified in *Daubert* may or may not be pertinent in assessing reliability, depending on the nature of the issue, the expert's particular expertise, and the subject of his testimony." 526 U.S. at 150. The Supreme Court in *Kumho* further held that:

we can neither rule out, nor rule in, for all cases and for all time the applicability of the factors mentioned in *Daubert*, nor can we now do so for subsets of cases categorized by category of expert or by kind of evidence. Too much depends on the circumstances of the particular case at issue.

*Id.*¹¹

Such reasoning is also consistent with our previous declination to "give any special significance to the *Daubert* factors," in the context of considering evidence we considered to be experience-based specialized knowledge. *Brooks*, 975 P.2d at 1114. In *Brooks*, we held that it was preferable to avoid discussing "whether or to what extent a court should apply the *Daubert* factors," and concluded instead, that the proper focus should be on "whether the evidence is reasonably reliable information that will assist the trier of fact." *Id.*

Any concerns that invalid scientific assertions will be admitted under this liberal standard are assuaged by Rule 702's overarching mandate of reliability and relevance. See *Daubert*, 509 U.S. at 595. Such concerns are also mitigated by "[v]igorous cross-examination, presentation of contrary evidence, and careful instruction on the burden of proof." *Id.* at 596. In addition, a trial court making a CRE 702 determination must apply its discretionary

authority under CRE 403 to ensure that the probative value of the evidence is not substantially outweighed by the danger of unfair prejudice, confusion of the issues, undue delay, waste of time, or needless presentation of cumulative evidence. *Id.*; *Campbell*, 814 P.2d at 8; *Hampton*, 746 P.2d at 951 n. 8. Finally, a trial court's CRE 702 determination must be based upon specific findings on the record as to the helpfulness and reliability of the evidence proffered. *Brooks*, 975 P.2d at 1114; *Campbell*, 814 P.2d at 8. The trial court must also issue specific findings as to its consideration under CRE 403 as to whether the probative value of the evidence is substantially outweighed by its prejudicial effect. *Brooks*, 975 P.2d at 1114; *Campbell*, 814 P.2d at 8.

To summarize, we conclude that CRE 702, rather than *Frye*, represents the appropriate standard for determining the admissibility of scientific evidence.¹² We hold that under this standard, the focus of a trial court's inquiry should be on the reliability and relevance of the scientific evidence, and that such an inquiry requires a determination as to (1) the reliability of the scientific principles; (2) the qualifications of the witness; and (3) the usefulness of the testimony to the jury. We also hold that when a trial court applies CRE 702 to determine the reliability of scientific evidence, its inquiry should be broad in nature and consider the totality of the circumstances of each specific case. In doing so, a trial court may consider a wide range of factors pertinent to the case at bar. The factors mentioned in *Daubert* and by other courts may or may not be pertinent, and thus are not necessary to every CRE 702 inquiry. In light of this liberal standard, a trial court should also apply its discretionary authority under CRE 403 to ensure that the probative value of the evidence is not substantially outweighed by unfair prejudice. Finally, we hold that under CRE 702, a trial court must issue specific findings as it applies the CRE 702 and 403 analyses.

D. Application of CRE 702 to Evidence at Issue

Having determined that CRE 702 represents the proper standard, we now turn to the issue of whether the evidence derived from the DNA testing techniques at issue in this case is admissible under that standard. The trial court below did not have the benefit of our ruling and instead employed a thorough *Frye* analysis to conclude that the evidence was inadmissible. Alternatively, the trial court applied the *Daubert* factors to reach the same result.¹³ Thus, a determination of admissibility under our new standard is required.

Because the record in this case is sufficient for a determination of admissibility under CRE 702, we need not remand the case to the trial court. Instead, we conclude that, under CRE 702's liberal standard for admissibility, the evidence derived from the PE kits at issue here is admissible.

As discussed above, admissibility under CRE 702 is appropriate when (1) the scientific principles at issue are reasonably reliable, (2) the witness is qualified to opine on such principles, and (3) the testimony will be useful to the jury. In this case, the parties do not question the qualification of the witness, nor do they dispute that the evidence will assist the jury. Thus, our main concern is whether the PCR-based multiplex STR system from which the evidence here was derived is sufficiently reliable.

We begin by discussing the admissibility of PCR and STR-based DNA testing, as we have not previously addressed this issue.¹⁴ The majority of courts in other jurisdictions that have considered the issue have held that DNA evidence derived from the PCR testing method satisfies the standards for admissibility under either *Frye* or Rule 702.¹⁵ Indeed, the National Research Council's Committee on Forensic DNA Science has concluded that the molecular technology on which PCR is based is thoroughly sound, and that the results are highly reproducible when appropriate quality-control methods are followed. *Shea*, 957 F. Supp. at 338-39.

Similarly, as the trial court has acknowledged, the National Institute of Standards and Technology ("NIST") has determined that there are several advantages of using STRs over conventional techniques, and that the use of STRs for genetic mapping and identity testing has become widespread among DNA typing laboratories. John M. Butler & Dennis J. Reeder, Short Tandem Repeat DNA Internet Database, <http://www.cstl.nist.gov/biotech/strbase/intro.htm>. As a result, many courts have found that DNA evidence derived from STR-based testing is admissible either under *Frye*'s general acceptance test or under Rule 702's reliability test.¹⁶ The wide acceptance of PCR and STR testing among scientists and courts in various jurisdictions indicates that the use of such systems in DNA analysis is reliable. Furthermore, the evidence in the record demonstrates that unlike RFLP testing, which destroys the sample, PCR processing allows for easy replication of test results by amplifying the sample. We are therefore convinced that DNA evidence derived from PCR-based testing, and specifically such evidence derived from the STR method is sufficiently reliable under CRE 702 to warrant admission in Colorado.¹⁷

The evidence at issue in this case was derived from a PCR-based STR multiplex system.¹⁸ Specifically, the Profiler Plus and Cofiler kits at issue here employed a combination sixplex and nineplex system. Having determined that PCR and STR-based testing are reliable under CRE 702, the issue before us now is whether the specific

multiplex testing performed in this case is sufficiently reliable under CRE 702 to warrant admission of the evidence derived from their use.

We agree with the trial court's conclusion that, in general, evidence derived from multiplex testing should be admitted. However, we reach this conclusion by applying CRE 702, rather than Frye. In doing so, we conclude, based on the scientific evidence presented under the totality of circumstances in this case, that multiplex testing is sufficiently reliable to warrant such admission. Evidence in the record of numerous studies concerning multiplex testing, widespread dissemination of multiplex information, and popular use of multiplex systems supports our conclusion.

According to NIST, multiplex, which involves adding more than one set of PCR primers to the reaction in order to target multiple locations, is an ideal technique for DNA typing because the probability of identical alleles in two individuals decreases with an increase in the number of polymorphic loci examined. Butler, *supra* at <http://www.cstl.nist.gov/biotech/strbase/multiplx.htm>. The NIST website indicates that monoplex and multiplex STRs are used extensively in the forensic field, and the site lists over 900 published articles detailing the use of STRs in population studies, medical research and diagnosis, and in the forensic field.

Indeed, the trial court acknowledged that one advantage to multiplexing is its ability to offer greater discrimination. The trial court also noted that multiplexing requires less material, fewer tests and thus is ideal in the forensic setting and saves time and money. In addition, because fewer tests are required, the risk of contaminating samples is reduced. While testing multiple loci in one test can be problematic because adding more than one set of PCR primers to a reaction may cause primers for one locus to complex with those of other loci, the reproducibility of test results under this process mitigates this risk. Furthermore, the numerous studies concerning multiplex testing and evidence in the record of widespread dissemination of multiplex information support its reliability.

The record indicates that the prosecution submitted fourteen studies addressing the consistency and reliability of the PE kits and their forensic use. Because the majority of the studies were conducted in foreign countries and because they were published in a book that was not well-known, the trial court concluded that they were not sufficiently peer reviewed. The trial court similarly dismissed a study performed in the United States by a well-respected expert in the field, and another validation study included by PE in its user's manual. The record also indicates that information about the multiplex method had been widely disseminated through numerous poster sessions and symposia. Although the trial court found that this failed to establish validation under strict TWGDAM guidelines and thus indicated no general acceptance under Frye, we reach a different conclusion under CRE 702. We find that the evidence in the record of numerous studies concerning multiplex, widespread dissemination of multiplex information, and popular use of multiplex systems indicates that multiplex systems are reliable under CRE 702.

The trial court acknowledged that triplexing, which is a form of multiplexing, is generally accepted. However, it nonetheless held that the sixplex and nineplex systems at issue in this case were not sufficiently validated or peer reviewed, and thus evidence derived from their use was inadmissible. We disagree.

As a preliminary matter, we disapprove of the trial court's distinction between the sixplex and nineplex systems at issue in the present case and other multiplex systems not at issue here that have been widely accepted by the scientific community.¹⁹

Such a fine distinction is not required under CRE 702's liberal standard for admissibility. See *Daubert*, 509 U.S. at 594 ("The inquiry envisioned by Rule 702 is, we emphasize, a flexible one."); *Bonds*, 12 F.3d at 565 (holding that a Rule 702 inquiry is "a flexible and more lenient test that favors the admission of any scientifically valid expert testimony").

We also conclude that questions as to the reliability of the particular type of multiplex kit go to the weight of the evidence, rather than its admissibility. *State v. Russell*, 882 P.2d 747, 768 (Wash. 1994) (holding that general acceptance under Frye of PCR kit was not required because the kit is simply one tool for carrying out generally accepted PCR methodology); see also *Hicks*, 103 F.3d at 848 (holding that challenges to laboratory protocols used in PCR testing do not weigh against the admissibility of PCR); *Shea*, 957 F. Supp. at 340 (concluding that concerns about handling and quality control procedures affect the weight that should be given to evidence, rather than its admissibility).

Finally, we are persuaded that the multiplex systems at issue in this case are sufficiently reliable by their acceptance by several other courts that have considered the issue.

Although our research reveals no appellate court decisions discussing the admissibility of DNA evidence derived from a multiplex system, the parties have submitted copies of several trial court rulings from other jurisdictions that have admitted DNA evidence derived from the very multiplex STR systems at issue here. *State v. Lynch*, No. CR 98-11390 (Ariz. Super. Ct. Aug. 17, 1999) (ruling that Profiler Plus and Cofiler kits were generally

accepted under Frye); *State v. Hill*, No. 232982 (Cal. Super. Ct. Apr. 18, 2000) (ruling that issue as to whether PE kit is generally accepted goes to weight, not admissibility and concluding that evidence derived from such kit is admissible under Frye); *State v. Bertsch*, No. 94F07255 (Cal. Super. Ct. Oct. 20, 1999) (ruling that PE multiplex kits were admissible under Frye's general acceptance test); *Commonwealth v. Gaynor*, No. 98-0965-0966 (Mass. Super. Ct. Apr. 13, 2000) (ruling that evidence derived from Profiler Plus and Cofiler kits was admissible under Daubert); *State v. Dishmon*, No. 99047345 (Minn. Dist. Ct. Mar. 2, 2000) (ruling that evidence derived from Profiler Plus and Cofiler kits was admissible under Frye).

For example, a Minnesota District Court found recently in *State v. Dishmon* that evidence obtained using the Profiler Plus and Cofiler kits was admissible. *Dishmon*, No. 99047345, slip op. at 13. That court concluded that because PCR-STR typing met the Frye test, general acceptance of the specific kits used was not required. *Id.* at 8. In the alternative, the court held that evidence presented in that case indicated that the Profiler Plus and Cofiler kits were generally accepted. *Id.* at 9.

Similarly, a Massachusetts court held recently that evidence derived from the Profiler Plus and Cofiler kits was reliable under Daubert. *Gaynor*, No. 98-0965-0966, slip op. at 2. That court reasoned, "Because the more recent testing consists of essentially a refinement in the STR system of analysis, which has been determined to be generally accepted in the scientific community, I find the recent test results to be reliable." *Id.* The court also determined that specific concerns about the Profiler Plus and Cofiler kits themselves were issues of weight, rather than admissibility. *Id.* at 5.

We are aware of only one trial court that has found the evidence derived from the Profiler Plus and Cofiler kits to be inadmissible. The Vermont District Court held in *State v. Pfenning* that evidence derived from the Profiler Plus kit was inadmissible because the kit had not been sufficiently validated or subjected to peer review under Daubert. No 57-4-96 (Vt. Dist. Ct. Apr. 6, 2000). Because we have determined that compliance with the Daubert factors is not determinative as to the question of admissibility, we are not persuaded by *Pfenning* because its analysis focuses on a particular factor under Daubert, holding that the absence of that factor defeats admissibility. See *Kumho*, 526 U.S. at 151 (noting that, "It might not be surprising in a particular case . . . that a claim made by a witness has never been the subject of peer review

. . . ."); *Heller v. Shaw Indus., Inc.*, 167 F.3d 146, 155 (3d Cir. 1999) (holding that, given the liberal thrust of the rules of evidence and the flexible nature of the Daubert inquiry, published studies on general causation are not required for admission of a medical expert's testimony).

Thus, after considering the totality of the circumstances in this case, we conclude that the evidence derived from the PE sixplex and nineplex STR systems is admissible under CRE 702 because (1) multiplex systems are generally reliable; (2) questions as to the reliability of a specific type of multiplex kit go to the weight of the evidence, rather than its admissibility; and (3) the specific multiplex kits used in this case have been deemed reliable by other courts. We also find that the probative value of the evidence derived from the kits used is not substantially outweighed by the danger of unfair prejudice, confusion of the issues, undue delay, waste of time, or needless presentation of cumulative evidence. Therefore, the evidence at issue here meets the requirements of CRE 403 and should be admitted. Accordingly, we make our rule to show cause absolute and order the trial court to vacate its order barring such evidence.

IV. CONCLUSION

We hold that CRE 702, rather than Frye, is the appropriate standard for determining the admissibility of scientific evidence in Colorado. We hold that under this standard, the focus of a trial court's inquiry should be on whether the scientific evidence is reasonably reliable and whether it will assist the trier of fact, and that such an inquiry requires a determination as to (1) the reliability of the scientific principles, (2) the qualifications of the witness, and (3) the usefulness of the testimony to the jury. We also hold that when a trial court applies CRE 702 to determine the reliability of scientific evidence, its inquiry should be broad in nature and consider the totality of the circumstances of each specific case. In doing so, a trial court may consider a wide range of factors pertinent to the case at bar. The factors mentioned in *Daubert* and by other courts may or may not be pertinent, and thus are not necessary to every CRE 702 inquiry. In light of this liberal standard, a trial court should also apply its discretionary authority under CRE 403 to ensure that the probative value of the evidence is not substantially outweighed by unfair prejudice. Finally, we hold that under CRE 702, a trial court must issue specific findings as it applies the CRE 702 and 403 analyses.

Applying this standard, we hold that DNA evidence derived from PCR-based testing is admissible under CRE 702. Similarly, we hold that evidence derived from STR systems, including STR multiplex systems, is also admissible under CRE 702. Finally, we conclude that the evidence at issue in this case, which was derived from kits

employing a combination sixplex and nineplex system, is sufficiently relevant and reliable under CRE 702 to warrant admission. Accordingly, we make our rule to show cause absolute and we order the trial court to vacate its order barring this evidence.

Notes:

1. The Profiler Plus kit reads nine loci while the Cofiler kit reads six loci, two of which are also read by the Profiler Plus kit.

2. 5.3 quadrillion = 5,300,000,000,000,000 = 5.3×10^{15}

3. *United States v. Yee*, 134 F.R.D. 161, 194 (N.D. Ohio 1990); *Fishback*, 851 P.2d at 891; *State v. Vandebogart*, 616 A.2d 483, 490 (N.H. 1992); *State v. Ford*, 392 S.E.2d 781, 783 (S.C. 1990).

4. Federal Rule of Evidence 702 provides: "If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise." Fed. R. Evid. 702.

5. In *Fishback*, we noted that the parties did not seriously dispute the applicability of *Frye* in determining the admissibility of DNA typing evidence. *Fishback*, 851 P.2d at 891 (noting also, however, that the notion that *Frye* was superseded by CRE 702 lacked merit because CRE 702 became effective in January 1980 and we adopted *Frye* in *Anderson*, which was decided in November 1981). Similarly, in *Lindsey*, we expressly stated that, "We do not consider the relative merits of the *Frye* test or our corollary state rules of evidence for the simple reason [that] the issue is not now before us." *Lindsey*, 892 P.2d at 288-89 (noting also that *Frye*'s general acceptance test is "not far removed from evaluation required under FRE 702" in that under CRE 702, a court must still screen the evidence to ensure its reliability, which may include consideration of the evidence's general acceptance).

6. In the absence of such a clear standard, the trial court below applied both a *Frye* and a *Daubert* analysis in determining the admissibility of the DNA evidence at issue. See *Fishback*, 851 P.2d at 896 (Mullarkey, J., concurring in the result only) (noting that, in light of the trial court's analysis under both *Frye* and CRE 702, "the time has come for this court to set forth clearly the standard by which novel scientific evidence should be assessed").

7. Courts have found that *Frye*'s ambiguity provides an opportunity to manipulate the terms "scientific community" and "general acceptance" in order to reach a desired result. *Downing*, 753 F.2d at 1236.

8. *Castro*, 545 N.Y.S.2d at 987.

9. As discussed above, although our decisions in *Fishback* and *Lindsey* relied on *Frye*'s general acceptance test to determine the admissibility of the DNA evidence at issue in those cases, we did not specifically evaluate the merits of *Frye* in relation to CRE 702. To the extent that these decisions are relied upon to argue that *Frye* is the appropriate standard governing the admissibility of scientific evidence, we disapprove.

10. CRE 702 is identical to the federal rule of the same number. See *supra* note 3.

11. Commentators have also criticized *Daubert*'s list of factors for its "amorphous structure, [in that it creates] various laundry lists of factors [that] are combined in arbitrary ways by nonexperts to produce unknown probabilities of accuracy to be balanced against unmeasured prejudices." *Ebert*, *supra*, at 230.

12. We decline to limit the applicability of CRE 702 to only the novel scientific evidence governed previously by *Frye*. Nothing in the text of the rule requires such a limitation, and our holding is consistent with that of the United States Supreme Court in *Daubert*, which expressly applied its holding to all scientific evidence. *Daubert*, 509 U.S. at 593 n. 11.

13. The trial court analyzed the evidence under the *Daubert* factors without any discussion of CRE 702's reliability or relevance prongs. After a brief discussion of each *Daubert* factor, the trial court concluded that several of them were not met and therefore, the evidence was inadmissible under *Daubert*.

14. The trial court determined, based on the evidence before it, and rulings from other jurisdictions, that DNA evidence derived from PCR-based STR testing is generally accepted under *Frye* and is thus admissible. As discussed below, we agree that such evidence is admissible, but make our determination under CRE 702.

15. *Shea*, 957 F. Supp. at 339 (holding that because PCR is based on sound scientific methods and has been generally accepted in both forensic and non-forensic settings, it readily satisfies Rule 702's reliability requirement); *Harmon v. State*, 908 P.2d 434, 440 (Alaska Ct. App. 1995) (holding that under *Frye*, there seems to be little question concerning the scientific acceptance of the theory underlying PCR DNA typing), overruled on other grounds by, *State v. Coon*, 974 P.2d 386, 391 (Alaska 1999); *People v. Wright*, 72 Cal. Rptr. 2d 246, 250 (Cal. Ct. App. 1998) (holding that DNA evidence derived from PCR testing was admissible under *Frye*); *People v. Pope*, 672 N.E.2d 1321, 1327 (Ill. App. Ct. 1996) (holding that PCR-based methods of DQ? typing and polymarker typing for

DNA identification are generally accepted under Frye); *State v. Hill*, 895 P.2d 1238, 1247 (Kan. 1995) (finding no error in the trial court's determination that PCR amplification evidence satisfied Frye); *State v. Moore*, 885 P.2d 457, 475 (Mont. 1994) (upholding trial court's finding that PCR testing is sufficiently reliable under Rule 702 for forensic purposes), overruled on other grounds by, *State v. Gollehon*, 906 P.2d 697, 700 (Mont. 1995); *Watts v. State*, 733 So. 2d 214, 223 (Miss. 1999) (holding that PCR testing produces reliable results); *State v. Dishon*, 687 A.2d 1074, 1086 (N.J. Super. Ct. App. Div. 1997) (holding that PCR was reliable because it was found to be generally accepted under Frye); *People v. Morales*, 643 N.Y.S.2d 217, 219 (N.Y. App. Div. 1996) (holding that PCR method had gained general acceptance under Frye); *Campbell v. State*, 910 S.W.2d 475, 478-79 (Tex. Crim. App. 1995) (holding that underlying theory of PCR DNA testing is valid under Rule 702).

16. *People v. Allen*, 85 Cal. Rptr. 2d 655, 659-60 (Cal. Ct. App. 1999) (holding that STR testing is generally accepted under Frye); *State v. Roth*, 2000 Del. Super. LEXIS 219, at *5 (Del. Super. Ct. May 12, 2000) (holding that single-source STR DNA evidence is reliable under Daubert); *State v. Rokita*, No. 5-99-0453, 2000 Ill. App. LEXIS 742, at *14 (Ill. App. Ct. Sept. 8, 2000) (noting that STR-based testing is now generally accepted in the relevant scientific community); *Commonwealth v. Rosier*, 685 N.E.2d 739, 743 (Mass. 1997) (holding that PCR-based tests, including STR, are scientifically valid); *State v. Jackson*, 582 N.W.2d 317, 325 (Neb. 1998) (holding that the trial court correctly determined that PCR-based STR DNA testing used in that case was generally accepted).

17. See *Brooks*, 975 P.2d at 1114 (holding that evidence is admissible if it is reasonably reliable and will assist the trier of fact).

18. As discussed above, multiplex systems add more than one set of PCR primers to a reaction so as to be able to amplify and run several loci simultaneously. In contrast, monoplex systems run each STR locus separately.

19. Indeed, while concluding that only monoplex and triplex STR systems are generally accepted, the trial court noted that the NIST website provides a list of fifty-two validation studies including validations of multiplex STRs, and lists of core STR loci, including monoplex, triplex, tetraplex, quintuplex, pentaplex, and heptaplex loci.
