prise. They concentrated on the behavior of the idler photons to help determine the role of the observer. They blocked the path of the right idler photon so that it could not reach the counter. Now if the counter recorded a photon, they could deduce that the signal photon took the route to the left. If the counter did not record a photon, the signal must have gone to the right. Because they were able to figure out the path of the signal, the photon acted like a particle, and the detector recorded a bright band instead of an interference pattern.

They next blocked the path of both left and right idler photons so that neither could reach the counter. By doing so, they could no longer distinguish paths, thus effectively removing themselves as observers. Nevertheless, the interference pattern was not restored. "The mere possibility that the paths can be distinguished is enough to wipe out the interference pattern," says Leonard Mandel, who conducted the experiments with Li-Jun Wang and Xing Yu Zou.

In the world of quantum mechanics, therefore, observations can be made without observers. That leaves one important question unanswered: If a tree falls in a forest and no one hears it, does it make a sound?—*Russell Ruthen*

Endless Endgame?

Chess masters down the centuries have held that in pawnless endgames, such as the position shown below at the left, the advantage of rook for knight normally cannot force a win. Best play, they intoned, inevitably leads to a draw—that frustrating outcome to the locking of mind and ego over the chessboard.

The masters were wrong. A program written by Lewis B. Stiller, a graduate student at Johns Hopkins University, and run for more than four hours on a Thinking Machines Corporation massively parallel computer, has found a way to win. In doing so, the program produced a winning line 223 moves long, by far the longest in the 1,000-year history of the world's most deeply studied game.

Like certain computer-solved mathematical proofs, the analysis is too complicated to be checked, except by another computer. "We ran the first 173 moves twice and did other kinds of checks, so it's very unlikely an error crept in," Stiller says. "Still, we're dealing with roughly 32 trillion operations, and a stray neutron might conceivably have bounced into the computer chips."

Stiller designed his program to analyze all possible endgames involving two kings, four pieces and no pawns. The task, which requires the generation and classification of about 100 billion positions, begins at the end: The computer produces the handful of possible winning positions and works backward from them, generating a branching and rebranching tree of analysis. The machine then determines whether the balance of forces leads to a win in the general case (that is, where the superior side is not immediately compelled to lose a piece).

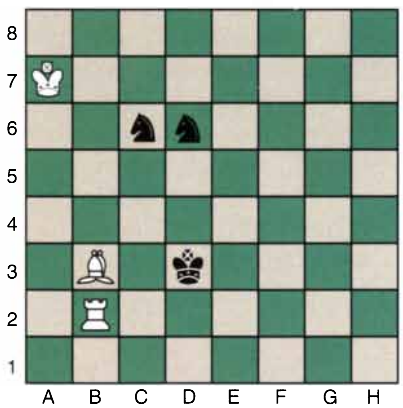
For the first 200 moves or so, the pieces seem to dance about aimlessly, conforming to no rules a human master might recognize and follow. Matters become clear only near the end, when the Black King's back is against the wall and its attendant knights can no longer protect one another. After 222 moves, the White King is about to occupy the square f5, forcing the win of a knight. The resulting struggle of king, rook and bishop against king and knight leads quickly and simply to checkmate.

Kenneth L. Thompson of Bell Laboratories was the first to apply retrograde analysis to computer chess. His program proved, for example, that king and queen win against king and two bishops—an endgame that chess manuals had concluded would end in a draw. Thompson's program exhausted the possibilities of five-piece problems, in one case finding a winning line of 71 moves.

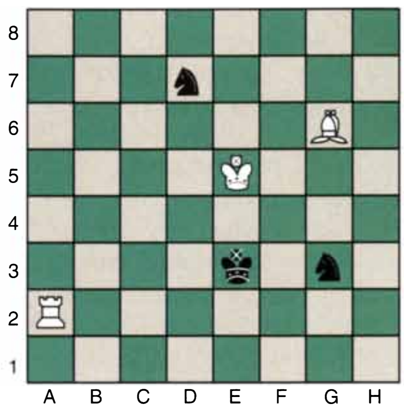
This unprecedented feat led the International Chess Federation to amend its rule on how long a game can proceed before it must be declared drawn. Previously a player had been required to force checkmate within 50 moves after the last capture of a piece or move of a pawn, on the all too human assumption that no winning line could possibly be longer.

Stiller refined Thompson's program to take advantage of the Connection Machine CM-2, which has 65,536 processors and eight billion bytes of memory. Thompson's one-processor algorithm had to incorporate an extra step to reduce the number of positions under review, whereas Stiller's parallel algorithm is simpler. It considers more positions but spends less time on each one.

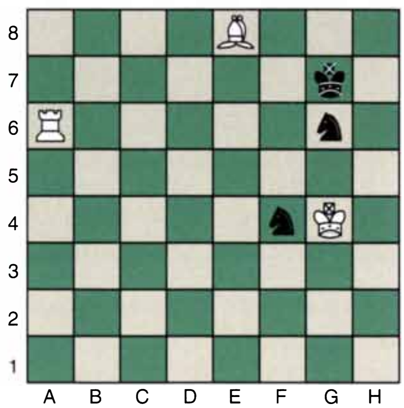
When playing from the initial position, however, computers still lose to the very best humans. Gary K. Kasparov, the chess champion of the world, has vowed that no machine shall ever defeat him. But although he has beaten Deep Thought, IBM's chess machine, its programmers expect to unveil a vastly improved version within a year or so. They say it will end the human domination of the chessboard forever. —*Philip E. Ross*



POSITION BEFORE WHITE'S FIRST MOVE



POSITION BEFORE WHITE'S 120th MOVE



POSITION AFTER WHITE'S 222nd MOVE