complete information but MAX does not. Among deterministic, partially observable games, Kriegspiel has received the most attention. Ferguson demonstrated hand-derived randomized strategies for winning Kriegspiel with a bishop and knight (1992) or two bishops (1995) against a king. The first Kriegspiel programs concentrated on finding endgame checkmates and performed AND–OR search in belief-state space (Sakuta and Iida, 2002; Bolognesi and Ciancarini, 2003). Incremental belief-state algorithms enabled much more complex midgame checkmates to be found (Russell and Wolfe, 2005; Wolfe and Russell, 2007), but efficient state estimation remains the primary obstacle to effective general play (Parker et al., 2005).

Chess was one of the first tasks undertaken in AI, with early efforts by many of the pioneers of computing, including Konrad Zuse in 1945, Norbert Wiener in his book Cybernetics (1948), and Alan Turing in 1950 (see Turing et al., 1953). But it was Claude Shannon's article Programming a Computer, for Playing Chess (1950) that had the most complete set of ideas, describing a representation for board positions, an evaluation function, quiescence search, and some ideas for selective (nonexhaustive) game-tree search. Slater (1950) and the commentators on his article also explored the possibilities for computer chess play.

D. G. Prinz (1952) completed a program that solved chess endgame problems but did not play a full game. Stan Ulam and a group at the Los Alamos National Lab produced a program that played chess on a 6 x 6 board with no bishops (Kister et al., 1957). It could search 4 plies deep in about 12 minutes. Alex Bernstein wrote the first documented program to play a full game of standard chess (Bernstein and Roberts, 1958).

The first computer chess match featured the Kock–McCarthy program from MIT (Kotok, 1962) and the ITEP program written in the mid-1960s at Moscow's Institute of Theoretical and Experimental Physics (Adelson-Velsky et al., 1970). This intercontinental match was played by telegraph. It ended with a 3-1 victory for the ITEP program in 1967. The first chess program to compete successfully with humans was MIT's MAC-IvK-6 (Greenblatt et al., 1967). Its Elo rating of approximately 1400 was well above the novice level of 1000.

The Fredkin Prize, established in 1980, offered awards for progressive milestones in chess play. The $5,000 prize for the first program to achieve a master rating went to BELLE (Condon and Thompson, 1982), which achieved a rating of 2250. The $10,000 prize for the first program to achieve a USCF (United States Chess Federation) rating of 2500 (near the grandmaster level) was awarded to DEEP THOUGHT (Hsu et al., 1990) in 1989. The grand prize, $100,000. went to DEEP BLUE (Campbell et al., 2002; Hsu, 2004) for its landmark victory over world champion Garry Kasparov in a 1997 exhibition match. Kasparov wrote:

The decisive game of the match was Game 2, which left a scar in my memory ... we saw something that went well beyond our wildest expectations of how well a computer would be able to foresee the long-term positional consequences of its decisions. The machine refused to move to a position that had a decisive short-term advantage—showing a very human sense of danger. (Kasparov, 1997)

Probably the most complete description of a modern chess program is provided by Ernst Heinz (2000), whose DARKTHOUGHT program was the highest-ranked noncommercial PC program at the 1999 world championships.

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*A Russian program, BESM may have predated Bernstein's program.*
In recent years, chess programs are pulling ahead of even the world's best humans. In 2004-2005 HYDRA defeated grand master Evgeny Vladimirov 3.5-0.5, world champion Ruslan Ponomariov 2-0, and seventh-ranked Michael Adams 5.5-0.5. In 2006, DEEP FRIKT beat world champion Vladimir Kramnik 4-2, and in 2007 RYBKA defeated several grand masters in games in which it gave odds (such as a pawn) to the human players. As of 2009, the highest Elo rating ever recorded was Kasparov’s 2851. HYDRA (Donninger and Lorenz, 2004) is rated somewhere between 2850 and 3000, based mostly on its trouncing of Michael Adams. The RYBKA program is rated between 2900 and 3100, but this is based on a small number of games and is not considered reliable. Ross (2004) shows how human players have learned to exploit some of the weaknesses of the computer programs.

Checkers was the first of the classic games fully played by a computer. Christopher Strachey (1952) wrote the first working program for checkers. Beginning in 1952, Arthur Samuel of IBM, working in his spare time, developed a checkers program that learned its own evaluation function by playing itself thousands of times (Samuel, 1959, 1967). We describe this idea in more detail in Chapter 21. Samuel’s program began as a novice but after only a few days’ self-play had improved itself beyond Samuel’s own level. In 1962 it defeated Robert Nealy, a champion at “blind checkers,” through an error on his part. When one considers that Samuel’s computing equipment (an IBM 704) had 10,000 words of main memory, magnetic tape for long-term storage, and a .000001 GHz processor, the win remains a great accomplishment.

The challenge started by Samuel was taken up by Jonathan Schaeffer of the University of Alberta. His CHINOOK program came in second in the 1990 U.S. Open and earned the right to challenge for the world championship. It then ran up against a problem, in the form of Marion Tinsley. Dr. Tinsley had been world champion for over 40 years, losing only three games in all that time. In the first match against CHINOOK, Tinsley suffered his fourth