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BOOK REVIEWS

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RICHARD. J NOWAKOWSKI (EDITOR), *Games of no chance 4*, Mathematical Sciences Research Institute Publications, Volume 63 (Cambridge University Press, 2015), x + 339 pp., 978-1-107-01103-8 (hardback), $94.99.

For many mathematicians of a certain generation, Martin Gardner's articles in *Scientific American* set them on their current career path in analysis, algebra, topology—or even recreational mathematics. Mathematical games or puzzles can be easy to describe and understand: some can be solved by a simple but subtle remark (e.g. that a standard chess board, with two opposite corner squares removed, cannot be covered by 31 two-by-one dominoes); others require fiendishly difficult arguments.

A *combinatorial game* (CG) is a two-player game where both players have full information on the game's position and there are no chance elements. To solve such a game is to give an efficient winning strategy. This was done for Nim in 1902, by Charles Bouton; in the 1930s, Roland Sprague and Patrick Grundy made considerable advances, followed by Richard Guy and Cedric Smith in the 1950s. John Conway's charisma and fertile curiosity since the 1960s have attracted many to this area.

The current book is the fourth in a series with similar titles, all edited by Nowakowski, and published as Mathematical Sciences Research Institute Volumes 29, 42, 56 and 63. They consist of papers based on presentations at the International Workshops on Combinatorial Games held in 1994, 2000, 2005 and (this volume) 2008, following the standard format: a brief preface, the articles, grouped by topic where convenient, and, to conclude, a whistle-stop account of currently unsolved problems in the field, alongside an updated bibliography of the subject. The contributors come from North America, continental Europe, Japan and Israel, but, surprisingly given the history of the area, none have a UK base. Some analysis of one-player games is also included.

CGs fall into one of two classes: normal games, where the winner is the one who makes the final move, and misère games, where the final mover loses. This volume contains several articles devoted to the latter family, which are generally found to be more difficult to analyse, including a study of the misère version of the classic children's game of Dots-and-Boxes, where each player aims to *minimize* the number of boxes they complete.

Many CGs have such an enormous number of possible positions that the use of vast computing power, allied to clever programming, can lead to optimal, or near-optimal, play. In 2016, such a program (AlphaGo) defeated a top-ranked Go professional for the first time; here several articles look at Go, or similar games; others discuss Hex (including variations such as handicapping the stronger player by allowing the other to colour N cells initially, and Bidding Hex, where both players have a finite number of chips with which to colour cells, but players bid to give up chips to the other for the right to make the next move). Conway's game of Sprouts is subjected to computer analysis: all versions that begin with 32 or fewer spots are now solved (later work has apparently extended this to 44 or fewer) and no counter-examples have yet been found to the

Sprouts Conjecture that the first player should win if, and only if, the initial number of spots is 3, 4 or 5 (modulo 6).

Other articles define and describe new or newish games. Rat, Mouse and Fat Rat are variations on Nim; MAZE and Toppling Dominoes were introduced by Nowakowski and colleagues only two years prior to the workshop; Clobber dates back only to 2001, but was introduced into the Computer Olympiad in 2005. Here a solitaire version of Clobber is investigated, the object being to leave as few stones as possible.

As one would expect, the book is attractively produced, with excellent diagrams and a careful layout. There is no index or glossary of terms, but the articles are very largely self-contained, with sufficient references to allow readers quickly to become familiar with the game and the methods used to attack it. The long period between workshop and book publication is regrettable, but the final bibliography takes readers to 2015, and the email addresses of all contributors are given.

JOHN HAIGH