Charles L. Dodgson, better known as Lewis Carroll, in a self-portrait from the 1880s.

MATHEMATICS

Logic and Lewis Carroll

As *Alice's Adventures in Wonderland* reaches 150, **Francine Abeles** surveys its creator's wide-ranging legacy.

In 1855, Charles L. Dodgson became the mathematical lecturer at Christ Church College in the University of Oxford, UK. His job was to prepare Christ Church men (for it was all men) to pass examinations in mathematics. Dodgson (1832–98) would go on to publish *Alice's Adventures in Wonderland* (1865) and *Through the Looking-Glass* (1871) under the pen name Lewis Carroll, but he also produced many pamphlets and ten books on mathematical topics.

In some of these, he exhibited unusual methods — for rapid arithmetic, for example. Others featured innovative ideas that foreshadowed developments in the twentieth century, for instance in voting theory. All but two of these books were published by Macmillan (until this year, the parent company of this journal's publisher). Macmillan co-founder Alexander Macmillan was Dodgson's trusted publisher and friend for 35 years (see go.nature.com/9q8oqe).

What unifies Carroll's oeuvre is the wit and colour apparent in the manifestations of his wide-ranging mathematical interests, particularly in geometry and logic. The *Alice* books contain many supreme examples. The “Mad Tea-Party”, for instance, has the Hare, Hatter, Dormouse and Alice circling around static place settings like numbers on a circle, as in a modular system, rather than in a line. Carroll developed the earliest modern use of today's ‘logic trees’, a graphical technique for determining the validity of complex arguments that he called the ‘method of trees’. This was a step towards automated approaches to solving multiple connected problems of logic. True to form, the puzzles that Carroll solves with his trees are given quirky names — “The Problem of Grocers on Bicycles”, “The Pigs and Balloons Problem”.

The ten sections of Carroll's book of droll mathematical stories, *A Tangled Tale*, first appeared between 1880 and 1885 as a serial in the popular magazine *The Monthly Packet*. Carroll dubbed each part a ‘knot’ to signify the difficulty of the one, two or three problems it featured. In the following issue of the magazine, he would summarize the puzzle, solve it and comment on the solutions he had received from readers, often amusingly presented (see <http://www.onlinemathlearning.com/tangled-tale.html>). *A Tangled Tale* became a favourite of Josiah Willard Gibbs (1839–1903), the applied mathematician and physical chemist praised by Albert Einstein as “the greatest mind in American history”.

Carroll believed that beyond their entertainment value, mental recreations such as games and logic puzzles

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To purchase an ebook on Lewis Carroll as logic puzzler, see go.nature.com/akxwma

conferred a sense of power on the solver. This, he felt, enabled them to analyse any subject clearly and, most important, to detect and unravel fallacies. In this vein, Carroll puns about other knots in *Alice's Adventures in Wonderland*. In Chapter 3, for instance, the Mouse responds to Alice's comments that he had got to the fifth bend in his tale (which appears on the page as a serpentine, tail-shaped paragraph) by crying, "I had not!" Carroll's ever-curious adventurer misunderstands amusingly: "A knot!" said Alice, always ready to make herself useful, and looking anxiously at her. "Oh, do let me help to undo it!"

Carroll was, of course, a devotee of word-play, as almost any page of *Alice's Adventures* and *A Tangled Tale* reveals. A fan of acrostics, Carroll dedicated the latter — published in book form in 1885 — to his friend and pupil, the 19-year-old Edith Rix, in the form of a poem that spells her name out in the second letter of each line:

*Beloved Pupil! Tamed by Thee,
Addish=, Subtrac=, Multiplica=tion,
Division, Fractions, Rule of Three,
Attest thy deft manipulation!*

*Then onward! Let the voice of fame
From Age to Age repeat thy story,
Till thy hast won thyself a name
Exceeding even Euclid's glory!*

In the last decades of his life, Carroll published three mathematical pieces in *Nature*. The first, on a method for finding the day of the week for any date (L. Carroll *Nature* 35, 517; 1887), reflects the ►

Books in brief

The Brothers Vonnegut: Science and Fiction in the House of Magic

Ginger Strand FARRAR, STRAUS AND GIROUX (2015)
Kurt Vonnegut, beloved troublemaker and science-fiction novelist, famously studied chemistry — but it was his brother Bernie who shone in the field. In this engrossing cultural history, Ginger Strand traces the brothers' intellectual development during the Second World War and its chill aftermath. Military interest led Bernie to research silver iodide as a trigger for cloud seeding at General Electric, and Kurt's horrifying experiences in combat inspired his inimitable fiction. Strand shows how both men, by calling in different ways for progress to be decoupled from conflict, revealed a rare integrity.

Thunder & Lightning: Weather Past, Present, Future

Lauren Redniss RANDOM HOUSE (2015)
Writer and artist Lauren Redniss's *Radioactive* (It Books, 2010; see G. Frazzetto *Nature* 469, 29; 2011) was a beautiful tour de force, meshing superb illustrations with an original telling of the lives of Marie and Pierre Curie. Now, in another aesthetically charged and deeply researched account, Redniss takes on meteorology. Here are phenomena from fog to cyclones; cloud types (a series of nebulous 'portraits'); the sensory appreciation of weather, such as Benjamin Franklin's air bathing, or snowfall's "muffled quietude" — and more. A wild rainstorm of a book, pelting the reader with ideas and inspiration.

Fallen Glory: The Lives and Deaths of Twenty Lost Buildings from the Tower of Babel to the Twin Towers

James Crawford OLD STREET (2015)
This multiple biography of vanished monoliths is itself monolithic, wending its way from Iraq to Manhattan and beyond. Standouts in the narratives built by writer James Crawford include the Tower of Babel, looming in manifestations from Mesopotamian Emperor Nebuchadnezzar's vast ziggurat Etemenanki to Pieter Bruegel the Elder's exquisite and disturbing 1563 painting. The Bastille, Roman Forum, Berlin Wall — all eloquently fall, along with New York's Twin Towers in the hideous events of 2001. My only quibble? No index.

The Orange Trees of Marrakesh: Ibn Khaldun and the Science of Man

Stephen Frederic Dale HARVARD UNIVERSITY PRESS (2015)
Six centuries ago, a Tunisian scholar created a new mirror for humankind. In his masterwork *Muqaddimah*, Ibn Khaldun (1332–1406) became the first person to approach history scientifically, by analysing social, economic and political evidence to reveal cycles of societal change. In this sober study, historian Stephen Frederic Dale argues that Ibn Khaldun's work is a key milestone on the road from Greek to Enlightenment thought, chiming with the radical reasoning of philosophers such as Montesquieu and Adam Smith.

Hamburgers in Paradise: The Stories Behind the Food We Eat

Louise O. Fresco (transl. Liz Waters) PRINCETON UNIVERSITY PRESS (2015)
Behind the whimsical title is a serious cultural history of food, newly translated from Dutch. Plant scientist Louise Fresco, a former assistant director-general of the Food and Agriculture Organization of the United Nations, argues that the trope of paradise as effortless abundance permeates humanity's tortured relationship with the edible. Her comprehensive trawl through biotechnology, supply chains and more concludes that — given more research and effort — a real paradise of plenty is within reach. [Barbara Kiser](#)

Alice's circular conversation with the Caterpillar is a gem of semantic wordplay.

ILLUSTRATION BY JOHN TENNIEL FROM ALICE'S ADVENTURES IN WONDERLAND (MACMILLAN, 1995)

► calendar problems of the time: to obtain information on future days and dates, you had to consult an almanac. Carroll found mental calculation methods gripping. Introducing the piece, he wrote, “I am not a rapid computer myself”; yet noted that he could do ten such problems in less than four minutes. His rule uses four integer calculations: two for the year, the third for the month and the last for the day.

In an era before calculators, standard arithmetic processes were onerous and prone to error. Carroll (writing this time under his real name) summarized his work on simplifying ordinary arithmetical calculations in his second piece in *Nature*, ‘Brief Method of Dividing a Given Number by 9 or 11’

“Carroll created a vivid tapestry of work, presaging in many ways developments in the twentieth century and beyond.”

(C. L. Dodgson *Nature* 56, 565–566; 1897) which also included division by 13, 17, 19 and 41, as well as by numbers within 10 from a power of 10, either way. The third piece, ‘Abridged Long Division’ (C. L. Dodgson *Nature* 57, 269–271; 1898), by his own admission, uses ideas put forth by others that he improved on, particularly an accuracy test. However, this paper has implications for modern computing in its emphasis on minimizing the number of steps in an algorithm.

Carroll did not influence his contemporary colleagues in the development of mathematical ideas. However, posthumously, beginning in the last half of the twentieth century, his contributions to voting theory were uncovered in three papers written between 1874 and 1876. The third, ‘A Method of Taking Votes on More Than Two Issues’, is the most important. Carroll was the first to create a voting method that would achieve biproportional representation — that is, proportionality with respect both to the population in the districts and to

Carroll's publisher, Alexander Macmillan.

the apportionment of seats to the political parties in the legislature. Despite Carroll's friendship with Lord Salisbury, the UK prime minister at the time, it was not applied for political reasons. (Today, the European Parliament uses a form of proportional representation.)

Carroll's work in logic, notably the unpublished second part of his book *Symbolic Logic*, foreshadowed results that appeared about 100 years later. This long-lost section, which contains the method of trees, was described by philosopher W. W. Bartley (*Sci. Am.* 227, 38–46; 1972). Carroll's book on linear algebra (*An Elementary Treatise on Determinants with Their Application to Simultaneous Linear Equations and Algebraic Geometry*, 1867) is also groundbreaking. His ‘condensation’ method for computing determinants sparked research that led to a formulation of the alternating sign matrix conjecture by David Robbins and Howard Rumsey in the 1980s. And his 1895 ‘What the Tortoise Said to Achilles’, a logic problem he published in the philosophical journal *Mind*, remains unsolved. In 1858, he was the first to create a cypher in matrix form based on a non-standard (modular) arithmetic; it was published more than 100 years later.

As a mathematician, logician, writer and innovative photographer, Carroll created a vivid tapestry of work, knotted, twisted and multistranded, and presaging in many ways developments in the twentieth century and beyond. Yet for all the complexity and playfulness of this master gamester's body of work — from voting theory to his great creation, Alice, on her long, strange journeys towards identity and maturity — his underlying concerns were fairness, certainty and truth. ■

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A love of puzzles is clear in the call to behead the bodyless Cheshire Cat: what, exactly, would you behead?

CHRONICLE/ALAMY

ILLUSTRATION BY JOHN TENNIEL FROM ALICE'S ADVENTURES IN WONDERLAND (MACMILLAN, 1995)