COMPUTER SCIENCE

Enchantress of abstraction

Richard Holmes re-examines the legacy of Ada Lovelace, mathematician and computer pioneer.

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Ada Lovelace, painted in 1835 by Margaret Sarah Carpenter.

The bicentenary of Augusta Ada King, Countess of Lovelace, heralds the critical reassessment of a remarkable figure in the history of Victorian science. Ada Lovelace (as she is now known) was 27 years old and married with 3 children when she published the first account of a prototype computer and its possible applications in 1843. Her 20,000-word paper was appended as seven Notes to a translation of a descriptive article, *Sketch of the Analytical Engine Invented by Charles Babbage, Esq*.

Lovelace's account was the fruit of one of the most intriguing collaborations in the annals of science: her friendship with Charles Babbage, Lucasian Professor of Mathematics at the University of Cambridge, UK, and inventor of the landmark analytical engine. The Notes eventually brought Lovelace both acclaim and notoriety. Babbage himself described her unforgettably to the physicist Michael Faraday as "that Enchantress who has thrown her magical spell around the most abstract of Sciences and has grasped it with a force that few masculine intellects (in our own country at least) could have exerted over it".

The exact nature of that force and enchantment continues to puzzle historians of science, not least because Lovelace's correspondence, largely archived at the Bodleian Library in Oxford, has not been fully published (see selections by Dorothy Stein in *Ada* (MIT Press, 1985) and Betty A. Toole in *Ada, Enchantress of Numbers*; Strawberry, 1992). What has emerged is the hitherto unsuspected range of Lovelace's interests and contacts, which linked the worlds of Victorian science and literature.

Lovelace was the only legitimate child of the poet Lord Byron. She never met her father, self-exiled in Italy and Greece, but inherited much of his rebellious spirit and something of his unstable genius. She directed it towards science, declaring: "I do not believe that my father was (or ever could have been) such a Poet as I shall be an Analyst (& Metaphysician); for with me the two go together indissolubly".

She was brought up with pathological severity by her mother, the brilliant Lady Annabella Byron — dubbed "the Princess of Parallelograms" for her own fascination with mathematics — and a squadron of female advisers whom Lovelace christened the Furies. Forbidden to read her father's poetry, young Ada was encouraged to study mathematics, astronomy and music, and allowed to design flying machines, play the harp and commune with her cat, Puff. In her early twenties she began to study the new calculus under Augustus De Morgan, a proponent of Boolean algebra, who described her as potentially more promising than any 'senior wrangler', or first-class Cambridge maths student.

In spring 1834, Lovelace met her first great

mentor: Mary Somerville, the translator of French astronomer Pierre-Simon Laplace and author of the groundbreaking popular study *On The Connexion of the Physical Sciences* (1834). Somerville demonstrated that women could make their mark in science (R. Holmes *Nature* **514,** 432–433; 2014). It was she who introduced Lovelace to Babbage at one of his champagne-and-science receptions in Marylebone, London, where Charles Darwin, astronomer John Herschel and geologist Charles Lyell were frequent guests. At these soirées, Babbage displayed a model of his early difference engine — a brass calculating machine capable of tabulating higher-order polynomial functions — alongside a silver automaton in the form of a dancing ballerina. Most guests were drawn to the ballerina; Lovelace, Babbage noticed, was entranced by the gleaming cogs of the calculating machine. Thus the unlikely friendship began.

When Ada married William King, later Earl of Lovelace, in 1835, her London town house brought her even closer to Babbage. Their mathematical correspondence, both serious and teasing, focused on the analytical engine and the possibilities of mathematical and symbolic calculation. Thus in 1840 Lovelace was discussing the elimination game solitaire, in which 26 marbles must 'jump' each other, in an apparently unpredictable sequence, until only one remains. She challenged Babbage to consider whether there could be "a mathematical formula … on which the solution depends, and which can be put into symbolical language". She added, "Am I too imaginative for you? I think not."

By 1841 Lovelace was developing a concept of "Poetical Science", in which scientific logic would be driven by imagination, "the Discovering faculty, pre-eminently. It is that which penetrates into the unseen worlds around us, the worlds of Science." She saw mathematics metaphysically, as "the language of the unseen relations between things"; but added that to apply it, "we must be able to fully appreciate, to feel, to seize, the unseen, the unconscious". She also saw that Babbage's mathematics needed more imaginative presentation. So when a scientific paper on the analytical engine was published by Italian engineer Luigi Menabrea, Lovelace (perhaps inspired by Somerville's translation of Laplace) translated it from the original French. A delighted Babbage encouraged her to add a commentary. When published in the British journal *Scientific Memoirs* (volume 3, October 1843), Lovelace's 'translator's Notes' had expanded to twice the length of Menabrea's paper, and were much more far-reaching. This is the work that eventually made both the engine and Lovelace famous. ▶

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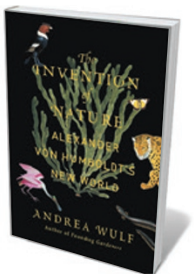
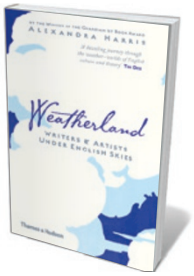
Books in brief

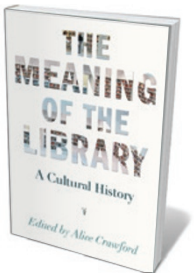


The Invention of Nature: Alexander von Humboldt's New World
Andrea Wulf KNOPF *(2015)*
Alexander von Humboldt (1769–1859) electrified fellow polymaths such as Johann Wolfgang von Goethe, discovered climate zones and grasped the impact of industrialization on nature. In her coruscating account, historian Andrea Wulf reveals an indefatigable adept of close observation with a gift for the long view, as happy running a series of 4,000 experiments on the galvanic response as he was exploring brutal terrain in Latin America. Most presciently, and at a time of fragmenting disciplines, he saw life as a "net-like intricate fabric" and brilliantly synthesized the sciences in his grand treatise *Cosmos*.

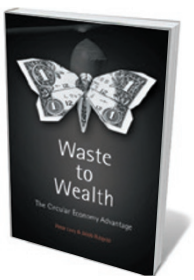
The Only Woman in the Room: Why Science Is Still a Boys' Club
Eileen Pollack BEACON *(2015)*
In the 1970s, Eileen Pollack was one of the first women to earn a bachelor's degree in physics at Yale University in New Haven, Connecticut. Isolated and unencouraged, she abandoned dreams of a life in cosmology and turned to writing. In this investigative memoir, Pollack uses her own experience and interviews with students and academics as a lens on gender and science. Many will wince in sympathy over the biases and sexism that made Pollack's academic career a salmon run to nowhere, yet despite ongoing inequalities in physics, she senses hopeful shifts in awareness.



Weatherland: Writers and Artists Under English Skies
Alexandra Harris THAMES & HUDSON *(2015)*
This is a gorgeous piece of writing, sure to grip bibliophiles and the meteorologically inclined alike. Scouring English art and literature for references to weatherscapes, Alexandra Harris has magicked them into a subtle meditation on the nation's changeable culture. Snippets of science intersperse discussions of Shakespeare's tempestuous dramas, the "gothic fogs" of Charles Dickens's 1853 *Bleak House,* the rain-soaked revelations of poet Ted Hughes and more. Harris captures the evanescent interplay of mind and sky, just as climate change could muddy that relationship out of all recognition.



The Meaning of the Library: A Cultural History
Editor Alice Crawford PRINCETON UNIVERSITY PRESS *(2015)*
The current pressures on libraries give a poignant edge to this chronicle, edited by research librarian Alice Crawford, which offers rarefied glimpses of the institution through time. Historian Andrew Pettegree reveals that printing contributed to the Renaissance library's decline; academic librarian Robert Darnton relates how eighteenth-century booksellers went through hell and high mountain passes to transport their wares; and English-literature professor Laura Marcus surveys libraries in films such as Alain Resnais's 1956 *All the Memories of the World* and Orson Welles' 1941 *Citizen Kane*.



Waste to Wealth: The Circular Economy Advantage
Peter Lacy and Jakob Rutqvist PALGRAVE MACMILLAN *(2015)*
In this crisply lucid primer on the innovative sustainable-business model called the circular economy, Peter Lacy and Jakob Rutqvist make a business case for repurposing wasted resources, life cycles and embedded values such as unrecovered energy. They sketch in the historical background; discuss worked examples of business models such as the circular supply chain; describe the creation of "circular advantage"; and map out strategies for making the shift to full sustainability. **Barbara Kiser**

Lovelace is sometimes loosely described as the first computer programmer. She did produce an elegant set of tables showing how the engine could calculate Bernoulli numbers, but based on equations supplied by Babbage. Lovelace's originality lay in her conceptual definitions of the engine's mathematical functions, and her brilliant speculations on its design possibilities, going far beyond anything Babbage himself articulated. She wrote: "We may say most aptly that the Analytical Engine weaves algebraic patterns just as the Jacquard-loom weaves flowers and leaves."

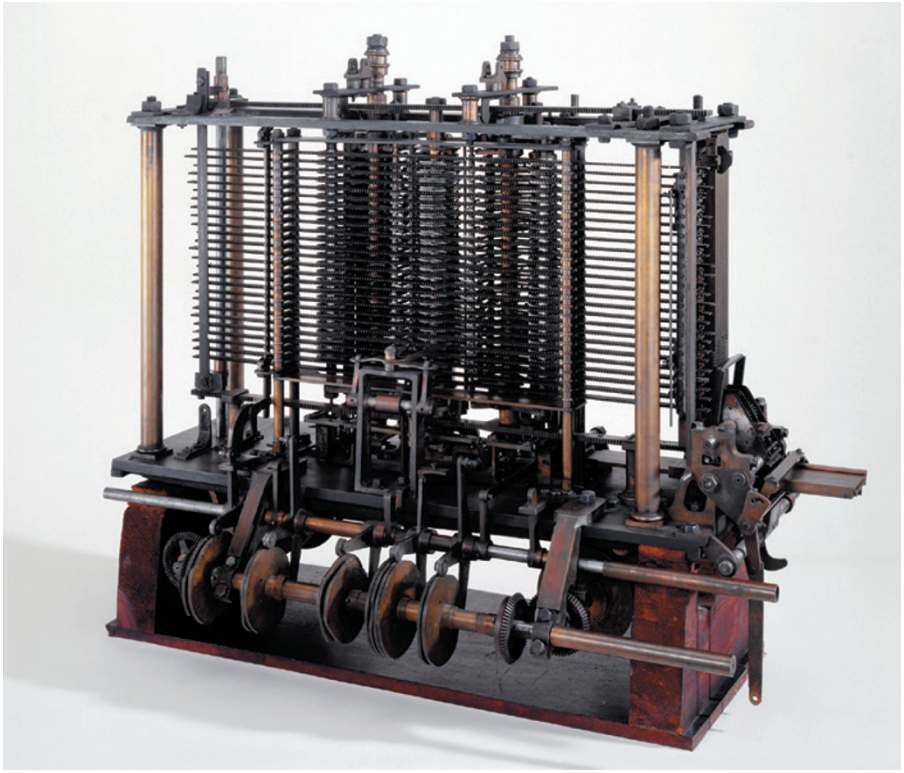
She distinguished it sharply from the difference engine and other "mere 'calculating machines'", writing prophetically that it "holds a position wholly its own … A new, a vast, and a powerful language is developed for the future". Like the Jacquard loom, it used paper punchcards that could program variable settings into a mechanical processor to be constructed from thousands of brass numerical cogs, vertically mounted in a system of calculating 'barrels', with 'loops and conditional branchings' built in. Despite having no defined power source, it was essentially the first genuine design for a working computer.

Next, Lovelace pointed out its revolutionary potential to handle purely symbolic notations, which gave it the potential to win games or compose music: "Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the Engine might compose elaborate and scientific pieces of music of any degree of complexity or extent."

Finally, she raised the question of whether the engine could think, but concluded that it "has no pretensions whatever to originate any thing". This was to have huge resonance. In his 1950 paper 'Computing machinery and intelligence', mathematician Alan Turing listed nine potential objections to the possibility of artificial intelligence (A. Turing *Mind* **59,** 433–460; 1950). The sixth was "Lady Lovelace's Objection" that a machine cannot do anything new; he initially agreed, then wondered about it. "A better variant of the objection says that a machine can never 'take us by surprise' … Machines take me by surprise with great frequency."

"Lovelace's originality lay in her definitions of the engine's functions, and her brilliant speculations on its design possibilities."

So does Lovelace. As her correspondence is gradually published, the extent of her scientific interests is emerging: they included railways, experimental telegraphy, magnetism, animal intelligence, probability theory and photography. Along with this is the multitude of luminaries whose work she knew, from Faraday to inventor Charles Wheatstone, engineer Isambard Kingdom Brunel, social theorist Harriet Martineau and novelist Charles Dickens.



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A portion of Charles Babbage's never-completed analytical engine, with printing mechanism.

Lovelace planned to draft many other scientific papers, for example on consciousness. These ambitions, latterly fuelled by opium, became increasingly visionary: "My own great scientific object … is the study of the Nervous System, and its relations with the more occult influences of nature." She wished to become "a Newton for the Molecular Universe" of the mind. Another paper was to be on the revolutionary field theories of Faraday, to whom she wrote boldly: "I mean (unless you discourage me) to undertake your Researches for review, or at any rate as my hinge and centre for an Electrical Article." By her thirties, aware of her own celebrity, Lovelace became increasingly provocative, speaking out on science, sex and life after death — "subjects few men and no women venture to touch upon", as her father's old friend, politician John Hobhouse, observed.

Lovelace died in great pain at 36, from uterine cancer. Almost her last independent act was visiting the Great Exhibition of 1851 with Babbage, to revel in scientific and technological advances — although both knew that the analytical engine would never be built in their own lifetimes. Both poetry and science attended her deathbed: Dickens came to read from his 1848 *Dombey and Son*; Lovelace wrote a sonnet on Newton's rainbow for her own tomb.

Lovelace's long-term influence has been as much cultural as scientific. She may have partly inspired Princess Ida in Alfred Tennyson's poem about a university of women, *The Princess* (1847). The precocious nineteenth-century teenager Thomasina Coverly in Tom Stoppard's 1993 play *Arcadia*, who understands chaos theory before it is established, was based on her. She is central to at least two science histories — James Gleick's *The Information* (Pantheon, 2011) and Walter Isaacson's *The Innovators* (Simon & Schuster, 2014) — as well as to Sydney Padua's hilarious (but scholarly) graphic novel, *The Thrilling Adventures of Lovelace and Babbage* (Particular, 2015).

Since 2009, an international Ada Lovelace Day has been celebrated every October, to promote women in science. The annual Lovelace Medal is awarded by the academy of the British Computer Society. A major academic conference will be dedicated to her work at the Mathematics Institute in Oxford in December (see go.nature.com/qn8yph). As Lovelace once wrote to a startled Faraday: "I would not miss a possible opportunity of being… useful to Science (Science whose Bride I am)!" ■

Richard Holmes *is the author of* The Age of Wonder, *which won the 2009 Royal Society Prize for Science Books, and* Falling Upwards.
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