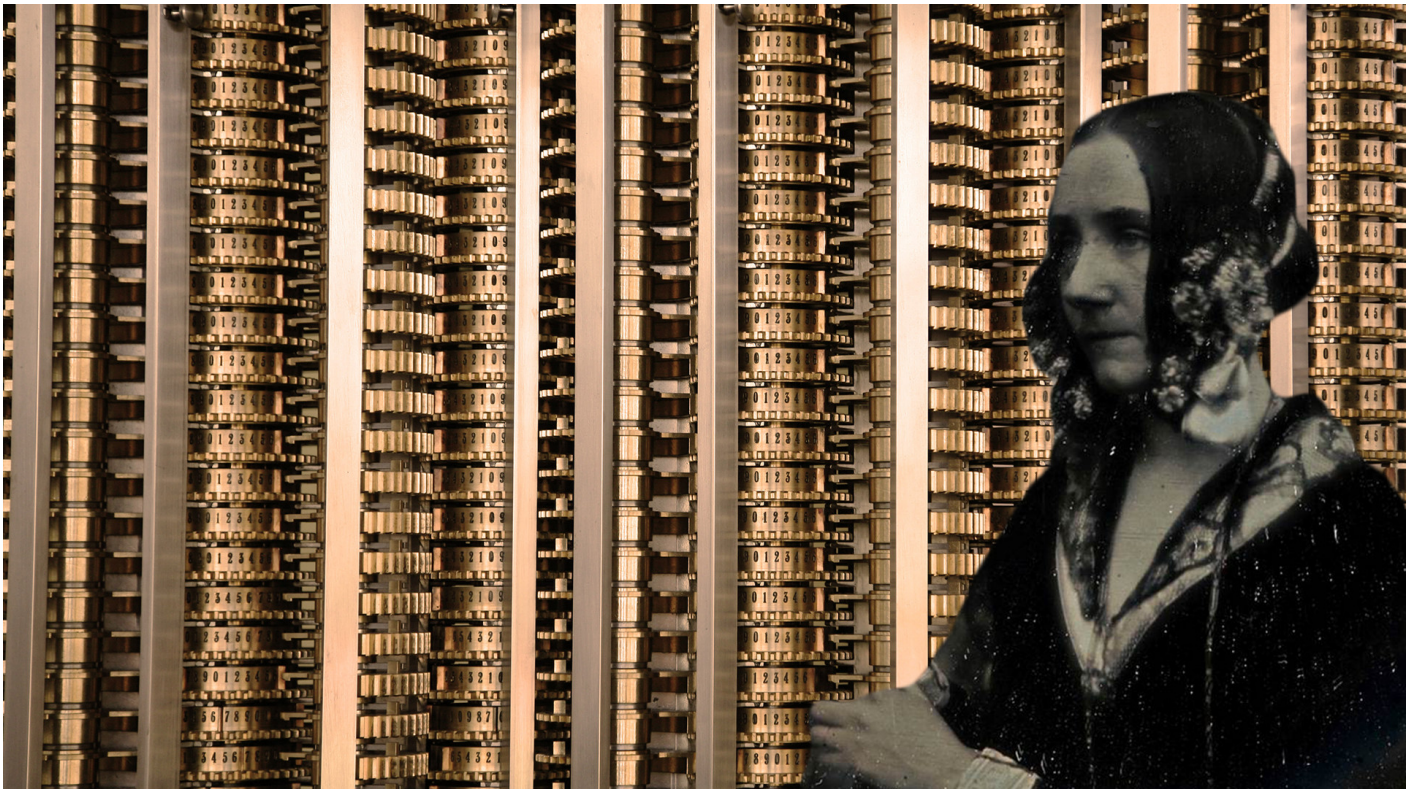


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The Scientific Life of Ada Lovelace Transcript

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The Scientific Life of Ada Lovelace

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Ada, Countess of Lovelace, was born Ada Byron on 10 December 1815, and died, after a long and painful illness, in 1852. The daughter of the poet Lord Byron, and his wife Annabella (nee Milbanke), she married in 1833 William King, who was created Earl of Lovelace in 1838.

Ada Lovelace is famous for a paper published in 1843, which translated and considerably extended a work by Luigi Menabrea about a general-purpose computer designed by Charles Babbage, his unbuilt analytical engine. The substantial appendices written by Ada Lovelace contain an account of the principles of the machine, and a table displaying how it might compute the Bernoulli numbers, often described as "the first computer programme".

From an early age, Lovelace showed a passion and a talent for mathematics and science: her mother was a noted educational reformer, and organised childhood visits to factories, which later helped Lovelace grasp the principles of Babbage's calculating machines, which she first encountered in her teens.

Charles Babbage said he conceived of the idea of computing tables of numbers "by steam" while he and the astronomer John Herschel were engaged in the tedious task of checking the values of a table computed by hand. 19th century science and business relied on a huge variety of such printed tables for matters such as navigation or interest calculations.

Babbage raised substantial government funds to build his "difference engine", a mechanical device to compute and print successive values of functions using the method of finite differences. Lovelace and her mother were frequent visitors to Babbage's regular soirees where he demonstrated working models of these devices – it was not until the 1990s that two complete difference engines were constructed to Babbage's designs – one is in the London Science Museum and one in the Computer History Museum in Silicon Valley.

After her marriage, and the birth of three children, Lovelace went back to mathematics and studied with one of the UK's pre-eminent mathematicians, Augustus De Morgan. In a remarkable two year correspondence course, preserved in Oxford's Bodleian Library, we see her working through the same material as De Morgan's students at University College London – limits, series, functions, differential equations and the like.

This background served Lovelace in good stead when she came to translate and extend Menabrea's article. While he prepared many notes and drawings, Babbage never published an account of his Analytical Engine, and the first account was published (in French) by Luigi Menabrea in 1842, based on lectures that Babbage gave in Turin.

Unlike the Difference Engine, Babbage's "analytical engine" was, in modern terms, a general purpose computer, programmed with punched cards, similar to the Jacquard cards used at the time to control looms. In principle it could calculate any function. Remarkably, Lovelace's paper presents it, not in terms of ironmongery, but as what we could now call an "abstract machine", describing the functions of memory, CPU, registers, loops and so on.

The paper contains a table illustrating the workings of the machine through the computation of the seventh Bernoulli number. This is often described as "the first computer programme". However Lovelace wrote, more accurately, that it "presents a complete simultaneous view of all the successive changes" in the components of the machine, as the calculation progresses. The "programme", had the notion existed at the time, would have been the stack of punched cards that caused the machine to make those successive changes, though Babbage's designs were rather unclear about aspects of how the cards would be manipulated, making it hard to reconstruct an explicit programme.

What is truly remarkable to the modern computer scientist reading the paper, and the correspondence between Lovelace and Babbage preserved in the British Library, is Lovelace's high level view, and how her speculation on the capabilities and potential of the machine mirror present-day concerns. Lovelace and Babbage's collaboration by letter, as they exchanged successive versions of the table for Bernoulli's numbers, echoes the frustrations of collaborators over the ages – "Where is it gone?" writes Babbage in a moment of frustration as they lose track of Note G.

She understands the complexity of programming

There are frequently several distinct sets of effects going on simultaneously; all in a manner independent of each other, and yet to a greater or less degree exercising a mutual influence.

the difficulty of verification

To adjust each to every other, and indeed even to perceive and trace them out with perfect correctness and success, entails difficulties whose nature partakes to a certain extent of those involved in every question where conditions are very numerous and inter-complicated

and the need for programme optimization.

One essential object is to choose that arrangement which shall tend to reduce to a minimum the time necessary for completing the calculation.

She reflects on the power of abstraction – explaining how the machine provides a link "between the operations of matter and the abstract mental processes of the *most abstract* branch of mathematical science and the role of the machine in supporting creativity. We might even invent laws for series or formulæ in an arbitrary manner, and set the engine to work upon them, and thus deduce numerical results which we might not otherwise have thought of obtaining".

Most famously, the paper is also remarkable for Lovelace's reflections on the potential of the machine. In what Turing later described as "Lady Lovelace's objection" to whether machines can think, she observed that "The Analytical Engine has no pretensions whatever to *originate* anything. It can do whatever we *know how to order it* to perform." She reflected on how the machine might do algebra, as well as compute with numbers, how it "*weaves algebraical patterns* just as the Jacquard-loom weaves flowers and leaves" and how if music could be represented algebraically "the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent."

When they hear about Lovelace, a mathematician's first question is often "But just how good a mathematician was she?" A modern answer about a modern mathematician might be in terms of

a professional framework of exam results, solving well-known problems, or winning famous prizes. But that was not the world in which Lovelace lived. In Cambridge mathematics was a required part of the university education – the Tripos - intended to develop skills in clear thinking rather than train professional mathematicians. Students were coached to solve stylized problems in algebraic manipulation or Euclidean geometry at great speed, with the top performer lauded as "Senior Wrangler". However, unlike continental Europe, there was not a developed culture of mathematical research. The utilitarian role of mathematics was paramount. A typical mathematics paper would most likely be based on calculation and examples, without proofs in the sense understood today: towards the end of Lovelace's life the power of abstraction was starting to emerge in Boole's and De Morgan's algebraic approach to logic, in Hamilton's creation of quaternions and in Cayley and Sylvester's development of the theory of invariants. To be a "mathematician" meant to think rationally about the world in a principled way, and to grasp the power of calculating from general principles, and getting to grips with numerical data. In this context Augustus De Morgan rated Lovelace highly. He despised the Cambridge Tripos, and organised his own teaching at UCL around fundamental principles rather than formulaic exams. Echoing typical views of the day, he felt the physical demands of the Cambridge Tripos would be too much for any woman, and especially someone like Lovelace who was dogged by ill-health. Rather, he praised her as someone whose power of thinking was "utterly out of the common way", capable of grasping the "real difficulties of first principles".

In later life, Lovelace continued to pursue her mathematical interests. Although she did no further work on Babbage's engines, Babbage and the Lovelace's remained friends. In one letter she asks whether peg solitaire could be modelled algebraically, and another charming document includes the Bridges of Konigsberg, a discussion of Pythagoras's theorem, and even a magic square. She contributed to her husband's writings on crops and husbandry, proposing a quadratic, rather than a linear, model to relate growth of plants to quantity of sunlight. She became interested in mesmerism, and reflected on whether there might be mathematical laws underlying the operations of the brain, a "calculus of the nervous system".

Lovelace's name lives on through the Ada programming language, initiatives for women in science, including the annual "Ada Lovelace Day" in mid-October. She has become a controversial figure, generating both wild enthusiasm, and, in turn, a back-lash of hostility, to extravagant claims that she foresaw quantum mechanics, invented the CD, or brought about Silicon Valley. There is no need to over-claim - in her 200th birthday year we can celebrate an extraordinary individual, who defied the constraints of her time and gave a remarkable and far-seeing account of the principles, potential and challenges of Babbage's analytical engine, and the many machines that have come after it.

Further reading

Computer science: Enchantress of abstraction, **Richard Holmes**, *Nature* 525, 30–32 (03 September 2015)

<http://www.nature.com/nature/journal/v525/n7567/full/525030a.html>

Innovators Assemble: Ada Lovelace, Walter Isaacson, and the Superheroines of Computing, Thomas Haigh, Mark Priestley, *Communications of the ACM*, Vol. 58 No. 9, Pages 20-27

<http://cacm.acm.org/magazines/2015/9/191176-innovators-assemble/fulltext>

A full list of biographies, and other information about Ada Lovelace and the current display at the Bodleian Library, can be found at <https://blogs.bodleian.ox.ac.uk/adalovelace/>

Images, and transcriptions by Christopher Hollings, of the De Morgan – Lovelace correspondence, and other mathematical writings of Ada Lovelace, will be released on-line at www.claymath.org in December 2015, thanks to the generosity of the Clay Mathematics Institute, and the descendants of Ada Lovelace.

A study of the mathematical correspondence between Lovelace and De Morgan is currently in preparation by Christopher Hollings, Ursula Martin and Adrian Rice.

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