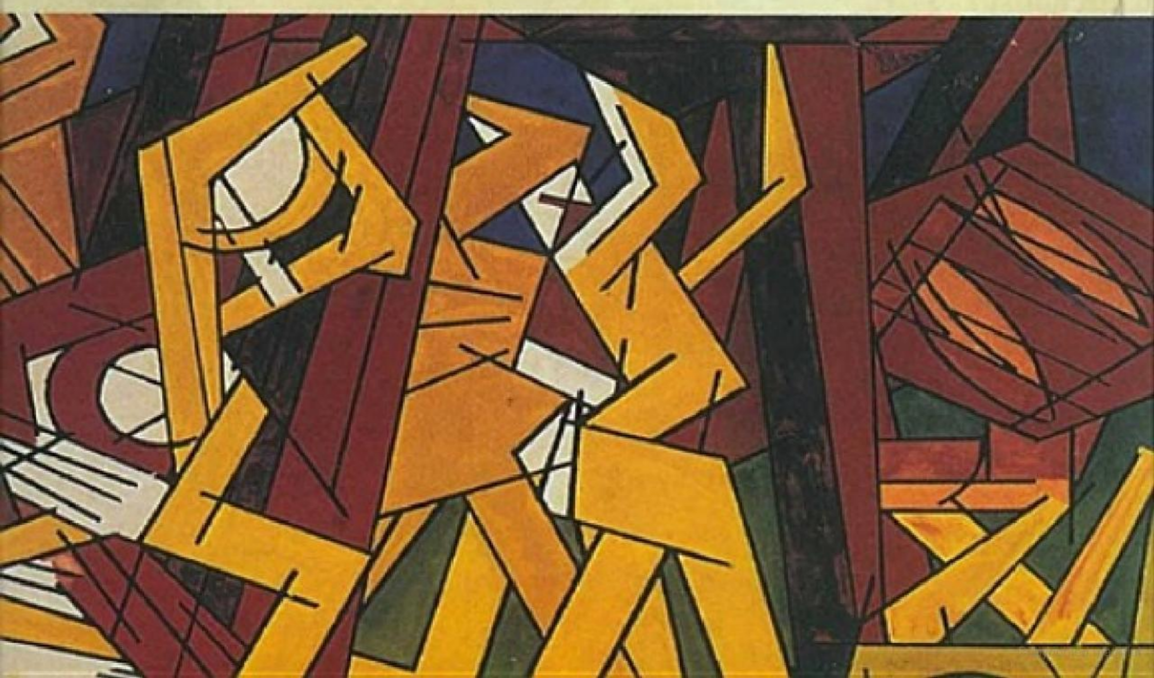
THE GREAT PHILOSOPHERS

ANDREW HODGES

Turing



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A Natural Philosopher

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PHOENIX

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INTRODUCTION

Alan Turing dared to ask whether a machine could think. His contributions to understanding and answering this and other questions defy conventional classification. At the close of the twentieth century, the 1936 concept of the Turing machine appears not only in mathematics and computer science, but in cognitive science and theoretical biology. His 1950 paper 'Computing machinery and intelligence', describing the so-called Turing test, is a cornerstone of the theory of artificial intelligence. In between, Turing played a vital role in the outcome of the Second World War, and produced single-handedly a far-sighted plan for the construction and use of an electronic computer. He thought and lived a generation ahead of his time, and yet the features of his thought that burst the boundaries of the 1940s are better described by the antique words: *natural philosophy*.

Alan Turing's immersion in and attack upon Nature was a unity; divisions between mathematics, science, technology and philosophy in his work have tended to obscure his ideas. He was not a prolific author; much remained unpublished in his lifetime; some remained secret into the 1990s. Private communications shed a little more light on the development of his thought, a subject on which he was generally silent. We shall see, for instance, how he came to logic and computation from a youthful fascination with the physical description of mind. But we have only hints as to the formation of his convictions amidst the secrecy of wartime cryptanalysis, and suggestions of fresh ideas are lost in the drama of his mysterious death.

communications, achieved under Turing's direction, was arguably the most vital aspect of Bletchley Park work. (2) Turing crowned the design of the machine (the 'Bombe') which was central to the analysis of all Enigma traffic, with a logical idea which had a curious echo of the discussion with Wittgenstein, as it depended on the flow of logical implications from a false hypothesis. (3) Turing created a theory of information and statistics which made cryptanalysis a scientific subject; he was chief consultant and liaison at the highest level with American work.

Practical work brought with it demands of co-operation and organisation to which Turing was unsuited, and in the early part of the war he had to fight a difficult corner on questions of strategy and resources, at one point joining with other leading analysts to appeal to Churchill over the heads of the administration. But there was another side to this uncongenial coin: war broke peacetime boundaries and gave him practical experience of technology at its leading secret edge. In peace his ideas had flowed into small-scale engineering; in war they led to the electronic digital computer of 1945.

Electronic speeds made a first impact on the Enigma problem in 1942, and thereafter in the engineering of very advanced large-scale Colossus electronic machines for breaking the other high-level German machine cipher, the Lorenz. Note, incidentally, that the Colossus was nothing to do with the Enigma, as is often lazily stated; also that Turing had no part in *designing* the Colossi, but had input into their purpose and saw at first-hand their triumph. Turing did, however, have an electronic design of his own: in 1944, he with one engineer assistant built a speech scrambler of elegant and advanced principle. It appears that in proposing the speech scrambler, not an urgent requirement, he had his own hidden agenda: to acquire electronic experience. The scrambler worked in 1945, and at the same time, Turing combined logic and engineering, pure and applied mathematics, to invent the computer.

Care with words and claims is required: the word 'computer' has changed its meaning. In 1936 and indeed in 1946 it meant a *person* doing computing, and a machine would be called an 'automatic computer'. Until the 1960s people would distinguish digital computers from analogue computers; only since then, as digital computers have swept the field, has the word come to mean a machine such as Turing envisaged. Even now, the word is sometimes applied to any calculating machine. In speaking of 'the computer', I take the salient feature to be that programs and data are alike regarded as symbols which may alike be stored and manipulated – the 'modifiable stored program' – and this is the feature implied by Turing in speaking of a 'practical universal machine', which is how he described his own idea.

Even here, however, care is required. Although the universal machine was presented in 1936 with instructions and working space all in the common form of the 'tape', the instructions only required reading, *not* manipulation or modification, so it would not matter if they were stored in some unalterable physical form. Turing recognized this and counted Babbage's Analytical Engine, on which instructions were fixed cards, as a universal machine. In practice, however, the recognition that programs and data could be stored alike in a symbolic form and could alike be manipulated, was immensely liberating. It made a clean break from the Babbage-like machines which culminated in the electronic ENIAC of 1946. In enunciating the power of the universal machine concept, Turing was far ahead of contemporary wisdom; his idea that a single type of machine could be used for all tasks was stoutly resisted well into the 1950s.

But in peace, Turing's ideas flowed also into philosophy; how did the war affect

Turing's philosophy? In *Alan Turing: the Enigma* I wrote that Christopher Morcom had died a second death in 1936, meaning that the concept of spirit freed from Laplacian determinism, which had stimulated Turing in 1930, would never be heard of again. It seemed to me strikingly clear that Turing's emotionally charged fascination with the problem of mind was the key to the mystery of how he, youthful outsider, had made a definitive and fundamental contribution with the concept of computability. By modelling the action of the human mind as a physical machine, he had brought radical new ideas into the world of symbolic logic. After 1936, it seemed, it was the powerful concept of the machine that had seized his imagination; and Turing's post-war writing would support this view. But in fact, his interpretation of ordinal logics in 1938 did leave the door open for something non-mechanical in the mind, and it now seems to me that Turing's views did not shift all at once in 1936 to espouse the total power of the computable.

My guess is that there was a turning point in about 1941. After a bitter struggle to break U-boat Enigma, Turing could then taste triumph. Machines turned and people carried out mechanical methods unthinkingly, with amazing and unforeseen results. This is when there was first talk between Turing and the young I.J. (Jack) Good about chess-playing algorithms. As I described in *Alan Turing: the Enigma*, this vision of mechanical intelligence must have stimulated great excitement; I would now go further and suggest that it was at this period that he abandoned the idea that moments of intuition corresponded to uncomputable operations. Instead, he decided, the scope of the computable encompassed far more than could be captured by explicit instruction notes, and quite enough to include all that human brains did, however creative or original. Machines of sufficient complexity would have the capacity for evolving into behaviour that had never been explicitly programmed. And it was at this period that he also lost interest in logic as a tool for probing reality – although it must be said that he retained a keen interest in theoretical computability *within mathematics*, being one of the first into the field when it was yoked to algebra in the late 1940s.

Possibly it was at the same time, or within months, that he also saw the megahertz speed of electronic components, and their reliable performance in the speech scrambling system used for telephone conversations between Roosevelt and Churchill. I suspect that it was only a short step to see the possibility of building a practical universal Turing machine in electronics. Certainly, by the end of the war, he was captivated by the prospect of exploring the scope of the computable on a universal Turing machine; and indeed he called it 'building a brain' when talking of his plans to his electronic engineer assistant.

Turing went to the National Physical Laboratory and worked on his detailed design for a computer, [9] submitting it for approval in March 1946. Turing's Automatic Computing Engine (ACE), as it was dubbed, was chronologically second to the June 1945 EDVAC report bearing von Neumann's name, but in addition to the originality of its hardware design, it was ideologically independent: for (1) it was conceived from the outset as a universal machine for which arithmetic would be just one application, and (2) Turing sketched a theory of programming, in which instructions could be manipulated as well as data.

It was an intensely exciting idea that engineering could be done once for all, so that new problems would only need paperwork. Of course, Turing had Bletchley Park as a model of how non-numerical and versatile machines might be urgently needed. Turing dramatised the range of possible operations with farsighted examples, of

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