6 Ideas Embodied in Metal: Babbage's Engines Dismembered and Remembered*

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Memory, that treacherous friend but faithful monitor, recalls the existence of the past.

(Charles Babbage, *The Ninth Bridgewater Treatise: A Fragment*, 1837)[1]

In the last few years of his life, although his memory for general matters had become impaired, he still retained a perfect recollection of the details of his workshops.

('Mr Charles Babbage', *Athenaeum*, October 1871)[2]

I began to think of making a small piece of Calculating Machinery to embody the ideas of my father . . . I wished, if I could, to justify the confidence he had shown in me by embodying some of his ideas in metal.

(Henry Babbage, *Memoirs and Correspondence*, 1915)[3]

It has often been said that museum collections embody memories, their artefacts and displays able to summon past experience through artful disposition. Complex assemblages of objects, texts, and people within and around museums allow the recall of what might otherwise seem lost or at least beyond reach. It is therefore perverse, if understandable, that such gatherings are so often used rather to evoke singular heroic individuals than to realise the extended webs

* Thanks for their generous help are due to Will Ashworth, Jenny Bulstrode, and Joshua Nall.

1 C. Babbage, *The Ninth Bridgewater Treatise: A Fragment*, 2nd edn (London: John Murray, 1838), p. 161.

2 'Mr Charles Babbage', *Athenaeum* no. 2296 (28 October 1871), p. 564.

3 H. Babbage, *Memoirs and Correspondence* (London: William Clowes, [?1915]), p. 225. The preface is dated August 1910; but the Science Museum Library copy (92 BAB) was inscribed to Henry's nephew Herbert Ivan, son of Benjamin Herschel Babbage, in April 1915. Other copies were also inscribed in 1915: see G. Tee, 'The Heritage of Charles Babbage in Australasia', *Annals of the History of Computing*, 5 (1983), pp. 45–59, on p. 47 n. 1; and I. Bernard Cohen, 'Babbage and Aiken', *Annals of the History of Computing*, 10 (1988), pp. 171–93, on p. 191.

of labour processes and social relationships embodied in each object. Museums in this sense risk becoming – or might deliberately aim to become – systems for the attribution and celebration of exclusive authorship and property.[4] Such highly charged dilemmas of collective and hagiographic memory and the prerogatives of ownership were especially marked in nineteenth-century exhibitions and galleries of science and art. Property relations, collective enterprise, and rights of labour were the very stuff of the political economy of display during the Age of Capital. A manifesto for the new Polytechnic Institution on London's Regent Street sent in 1839 to a nearby resident and supporter, the mathematician Charles Babbage, explained how the costly investment in 'its laboratory, its theatre and its splendid Gallery is well adapted for the display of scientific discoveries and were it truly in scientific hands, so that scientific discoveries were thrown off *hot* from the brain and before they had become public property by publication, sufficient novelty would be produced to excite public attention and to make it pay'.[5]

Dominant centres of scientific inquiry and accumulation, museums sustained vital if troublesome linkages between sites of artisan manufacture in urban workshops and the emergent factory system and sociable realms of theatre and consumption. Objects on show, turned into commodities, depended quite directly on hosts of workers, clients, and patrons elsewhere, while the status of technical knowledge embodied in such objects hinged on how they were publicly displayed.[6] Museums and galleries were made into repositories of historical narratives and travellers' tales. In a society cultivating a renewed obsession with sentimental and evocative relics and memorials, powerful fantasies of access to the past and the exotic were nourished by this set of relations, even though their realities

4 R. Lumley (ed.), *The Museum Time-Machine: Putting Cultures on Display* (London: Routledge, 1988); S. Crane (ed.), *Museums and Memory* (Stanford: Stanford University Press, 2000); and S. Vackimes, *Science Museums: Magic or Ideology?* (Almeria: Albedrio, 2008).

5 Cayley to Babbage, November 1839, British Library MS Add.37191, fol. 271 (stress in original); see B. Weeden, *The Education of the Eye: History of the Royal Polytechnic Institution* (Cambridge: Granta, 2008), pp. 12–13.

6 I. R. Morus, 'Sights and Sites: The National Repository and the Politics of Seeing in Early Nineteenth-Century England', in C. Berkowitz and B. Lightman (eds.), *Science Museums in Transition: Cultures of Display in Nineteenth-Century Britain and America* (Pittsburgh: University of Pittsburgh Press, 2017), pp. 87–107, on p. 89 (on the status of applied knowledge); and J. Bulstrode, 'The Industrial Archaeology of Deep Time', *British Journal for the History of Science*, 49 (2016), pp. 1–25, on pp. 16–23 (on exhibits and embodiment).

were often effaced.[7] Public museums were stocked with loot from antiquarian and oriental sites brought to the metropole through military and rapacious expeditions. They hosted technical equipment designed to signal the recoverable past and conjectural future of a politically and economically unstable society.

No doubt the fraught connections that flourished in Victorian capitals between state agencies, private accumulation, and commercial projects gave such displays significance. Commenting on the display of newfangled calculating engines at the 1862 South Kensington international exhibition, the medical statistician William Farr of the General Register Office explained that ‘there are besides the thousands of machines in the clouds of inventors’ brains, many ingenious and beautiful machines in exhibitions of no practical use whatever. How can the spectator know whether they will execute genuine work at all?’ Judgment depended on objects’ track records and their makers’ promises. For a candidate to be judged a discovery or invention, expert public communities had somehow to go back over traces of labour and material manipulation in a kind of retrospective inquiry: the exhibitions helped nourish these genealogical exercises and were subject to radical criticism from artisan activists keen to redistribute the property rights of inventors and masters.[8] In priority disputes and labour conflict, museological memory became a matter of material politics. Connections with the accumulated records and imagined future of labour and materials made such shows resemble devices that might somehow move through time, through the reconstruction, conservation, and show of their culture’s antecedents and subjects. This was an indispensable aspect of what has been called the museums’ ‘uncanny social technology’. Reflection on museological memory thus highlights themes such as the hard labour of salvage and reconstruction and the commemorative practices of nostalgia and piety.[9]

7 D. Lutz, *Relics of Death in Victorian Literature and Culture* (Cambridge: Cambridge University Press, 2015), pp. 8–9; and A. Craciun, *Writing Arctic Disaster: Authorship and Exploration* (Cambridge: Cambridge University Press, 2016), pp. 34–7.

8 W. Farr, *English Life Table* (London: Longman, 1864), p. cxxxix. See W. J. Ashworth, ‘England and the Machinery of Reason 1780–1830’, *Canadian Journal of History*, 35 (2000), pp. 2–36; C. Pettitt, *Patent Inventions: Intellectual Property and the Victorian Novel* (Oxford: Oxford University Press, 2004), pp. 88–110; and C. Macleod, *Heroes of Invention: Technology, Liberalism and British Identity 1750–1914* (Cambridge: Cambridge University Press, 2007), pp. 153–80.

9 For ‘uncanny social technology’ see D. Preziosi, ‘Brain of the Earth’s Body: Museums and the Framing of Modernity’ (1996), cited in T. Baringer, ‘Victorian

Themes that became especially significant included the exhibition of technology in museums. The display of machinery helped turn such museums into something like memory devices. This transformation was especially marked because of the vexed issue of the ownership of technology. In London between 1820 and 1833 Babbage was engaged in producing a calculating engine to manufacture mathematical tables for fiscal and navigational purposes. Significant public cash was invested in the engine, its assembly dependent on pugnacious and mutable relations with skilled labour in the city's machine-tool workshops. His scheme had to turn memory into mechanism in intricately indispensable features of the engine's operation. He worked out the mechanical principle for his difference engine to govern each of its figure wheels during carriage, the process in which wheels were compelled to pass from nine back to zero. Memory was embodied both in the machine and in the relations established by the machine's display. Writing of what he called Babbage's proposition 'to substitute an automaton for a compositor', the industrial publicist and science lecturer Dionysius Lardner observed that this vital principle involved 'in effect a *memorandum* taken by the machine of a carriage to be made'. In a timely polemic about industrial expositions, intellectual property, and the calculating engines written for the Great Exhibition, Babbage himself claimed that 'there is in this mechanism a certain analogy with the act of memory'. During such carriage, a lever was pushed back, 'the equivalent of the note of an event made in the memory', then a spiral arm would restore the lever and register the new number, a movement which 'in some measure resembles the endeavour made to recollect a fact'.[10]

Dependent on workers' skilful gear-cutting and draftsmanship, these processes of mechanised memory formed part of a practical culture of labour and performance, systematically embodied in the

Culture and the Museum', *Journal of Victorian Culture*, 11 (2006), pp. 133–45, on p. 133. Compare R. Altick, *The Shows of London* (Cambridge: Belknap Press, 1978), pp. 375–89; and I. R. Morus, 'Manufacturing Nature: Science, Technology and Victorian Consumer Culture', *British Journal for the History of Science*, 29 (1996), pp. 403–34.

10 [D. Lardner], 'Babbage's Calculating Engine', *Edinburgh Review*, 59 (July 1834), pp. 263–327, on p. 297 (my stress); C. Babbage, *The Exposition of 1851*, 2nd edn (London: John Murray, 1851), p. 182. Compare C. Babbage, *Passages from the Life of a Philosopher* (London: Longman, 1864), p. 62: 'the mechanical means I employed to make these carriages bears some slight analogy to the operation of the faculty of memory'; see W. J. Ashworth, 'Memory, Efficiency and Symbolic Analysis: Charles Babbage, John Herschel and the Industrial Mind', *Isis*, 87 (1996), pp. 629–53, on pp. 649–52; and M. L. Jones, *Reckoning with Matter: Calculating Machines, Innovation and Thinking about Thinking from Pascal to Babbage* (Chicago: University of Chicago Press, 2016), pp. 47–55.

urban milieux of display. The difference engines' fate was largely governed by the complex class topography of artisan and managerial enterprise. The Lambeth journeyman Richard Wright, who started as Babbage's valet in the late 1820s before touring the principal northern engineering works and becoming a master artisan for Babbage's mechanics projects, explained how paperwork and metalwork had to be combined in the calculating engine: 'a journal carefully connecting the different parts might serve the future as a perfect guide for its completion'.[11] The decisive experience of young workmen such as the Manchester artisan and lathe-maker Joseph Whitworth, who worked for the master engineer Joseph Clement in south London on the calculating engine project in 1830–1, confirmed Wright's judgment that the project's reputation as a training system was significant: 'a man who has worked at it has a greater chance of the best work', Wright told Babbage from Manchester. Though an indispensable component of drives to automate and mechanise production, the machine tools designed by Clement and Whitworth demanded ever more intense craft skills in forging, assemblage, and maintenance; and the valorisation of such artefacts relied on reputation and the memory of workers' skill.[12]

Paper and metal memoranda passing between centres of calculation and of work defined this topography's troubles. Conflicts about the disciplinary and labour systems of the naval dockyards, involving several of the engineers who would form Babbage's closest collaborators, had already intensely raised the basic spatial and political problems of inscribed plans, artisan skill, and managerial control.[13] Babbage's relations with his government patrons and with Clement's team hinged significantly on the physical and social distance between Lambeth workshops, Whitehall offices, and Babbage's domestic quarters in fashionable Marylebone. The machine eventually became memorable for its notoriously disjointed makers and dismembered materials. It was said 'Mr. Babbage made Clement. Clement made Whitworth. Whitworth made the tools.' 'When I first employed

11 Wright to Babbage, 25 September 1859, British Library MS Add.37197, fol. 440.

12 N. Atkinson, *Sir Joseph Whitworth, the World's Best Mechanician* (Stroud: Sutton, 1996), pp. 26–7; Wright to Babbage, 18 June 1834, British Library MS Add.37188, fol. 390. See R. Samuel, 'Workshop of the World: Steam Power and Hand Technology in Mid-Victorian Britain', *History Workshop Journal*, 3 (1977), pp. 6–72, on pp. 39–40.

13 P. Linebaugh, *The London Hanged: Crime and Civil Society in the Eighteenth Century* (London: Penguin, 1993), pp. 371–401; and W. J. Ashworth, 'System of Terror: Samuel Bentham, Accountability and Dockyard Reform during the Napoleonic wars', *Social History*, 23 (1998), pp. 63–79.

Clement', Babbage bitterly recalled, 'he possessed one lathe (a very good one) and his workshop was in a small front kitchen. When I ceased to employ him he valued his tools at several thousand pounds and he had converted a large chapel into workshops.'[14] Whitworth and Clement both occupied sacred places in Samuel Smiles's pantheon of heroic nineteenth-century engineers: eventually, Clement's workshop was broken up by his nephew Wilkinson, and the relics of the calculating-machine project held there were dismantled and melted down.[15] As relations with Clement soured in the early 1830s, the new chief draftsman Charles Jarvis privately advised Babbage that 'the plan I wish to recommend is that the designs and drawings be all made on your premises and under your immediate inspection'. The eminent engineer Marc Brunel agreed: the engine must be built at a site 'close to your own garden', certainly not where the new Whig administration proposed, in a workroom at the British Museum. The Treasury even suggested that Babbage might be persuaded to 'take a residence nearer to the Museum'.[16]

Though the difference engine was never fully completed, various of its components and relics were in fact destined to spend time nearer and often inside museums and showrooms. Once on display, the calculating machine was welded to histories of its development and fate: memoirs of its construction, funding, ownership, and disassembly always formed part of every attempt to explain its function. The principal material realisation of the addition and carriage mechanisms, completed in late 1832, was kept for display in his Marylebone drawing room and shown to Babbage's house guests in re-enactments of the engine's philosophical and economic lessons about mind and matter.[17] Other models of the difference engine were proposed. In 1834 Babbage's publicist Lardner toured northern England and Scotland lecturing on the engine's capacities, reportedly drawing vast crowds and cash. He hired the Charing Cross instrument-maker Francis Watkins, former apparatus curator at University College London, where Lardner briefly occupied the

14 Babbage memorandum, 9 November 1869, British Library MS Add.37189, fol. 499.

15 S. Smiles, *Industrial Biography: Iron Workers and Tool Makers* (London: John Murray, 1863), pp. 253–7; and H. Babbage, 'Babbage's Analytical Engine', *Monthly Notices of the Royal Astronomical Society*, 70 (1910), pp. 517–20, on p. 518.

16 Jarvis to Babbage, 25 August 1833, British Library MS Add.37188, fol. 39; and Brunel to Babbage, 11 January 1831, British Library MS Add.37185, fol. 439. See Jones, *Reckoning with Matter*, pp. 206–7.

17 H. Babbage, *Memoirs and Correspondence*, p. 89; Babbage, *Passages from the Life of a Philosopher*, pp. 425–6; Babbage, *The Ninth Bridgewater Treatise*, pp. 32–43.

natural philosophy chair until 1831. Over the winter of 1833–4, in consultation with Babbage and aided by drawings from Babbage's eldest son Benjamin Herschel Babbage, Watkins produced two steel models of the carriage mechanisms and the printer of the difference engine.[18] Lardner then sought to use the models in Manchester, Liverpool, and Sheffield and at the Royal Institution and the British Association, grumbling whenever deprived of the apparatus for his performances. Organisers complained, in turn, that the theme was 'too hard and too scientific': 'I find I have too much disregarded and looked down upon the exhibition of apparatus.' Babbage contacted allies such as Alexander von Humboldt in Berlin, and the Paris science writer and educator Charles Dupin, who went to one of Lardner's shows, to recruit interest in the tour and extend it Europe-wide.[19]

The lectures coincided with further abortive attempts to make demonstration models of the engine. In early 1834 the young Harvard-trained physician Henry Ingersoll Bowditch, who spent 'nearly a whole day and the greater part of the night' at Dorset Street examining the engine, begged Babbage for guidance: 'expense would be to me of little moment, could I hope to shew in America a work of art, which might excite in many a mind trains of thought, which might otherwise remain dormant . . . It is the hope of producing some such beautiful result that I wish to present to the scientific world of America, and the mechanics of Boston, a model of the calculating machine.' Bowditch planned to recruit the American instrument-maker Joseph Saxton, colleague of Watkins at London's premier mechanics showroom, the Adelaide Gallery, to produce the device. Saxton promised to visit Babbage to examine the possibilities. Just as negotiations between Babbage and Clement began to collapse, it had become evident that demonstration of the principles of the

18 Watkins to Babbage, 31 December 1833 and 15 January 1834, British Library MS Add.37188, fols. 119 and 160; Lardner to Babbage, [1833], British Library MS Add.37188, fol. 203. See B. Gee, *Francis Watkins and the Dollond Telescope Patent Controversy*, ed. A. McConnell and A. D. Morrison-Low (Farnham: Ashgate, 2014), pp. 276–83.

19 Babbage to Dupin, 30 December 1833, British Library MS Add.37188, fol. 117; Babbage to Humboldt [1833], British Library MS Add.37188, fol. 123; and Lardner to Babbage, 3 January, 11 January, 23 January, 16 February, and 16 October 1834, British Library MS Add.37188, fols. 140, 154, 176, 208, and 494. See J. N. Hays, 'The Rise and Fall of Dionysius Lardner', *Annals of Science*, 38 (1981), pp. 527–42, on p. 529. In 1839 Babbage and Lardner became embroiled in fierce disputes about railway gauges on I. K. Brunel's Great Western Railway.

calculating engine required what Lardner called 'the trickery of the lecture table by the introduction of apparatus'.[20]

When finally abandoned, the relics of the engine, so Babbage recommended, 'should be kept in a warm well-ventilated room', perhaps as a guard against rust and decay, and 'placed where the public can see it, for example the British Museum'. There, he intended, 'it would form a beautiful specimen of the state of the mechanical arts at the time when it was made', a souvenir of skill embodied in mechanism. By summer 1843 it was decided to shift it from Marylebone to the Museum at King's College on the Strand, and the brass, gun metal, and steel parts associated with it were crudely valued for scrap. 'The property should remain in the Government, in the event of its being at any time hereafter required for public use.'[21] Though excluded from the Crystal Palace in 1851, in 1862 it was shifted to South Kensington under the management of the railway engineer William Gravatt, as part of the subsequent international exhibition of industry. To Babbage's fury, King's College refused its return.[22]

In 1872, the year after Babbage's death, his eldest son Benjamin, by then a South Australian engineer, surveyor, and enthusiastic wine-grower, composed a small guidebook for the model machine to aid museum visitors. Benjamin added a drawing he'd made of the

20 Bowditch to Babbage, 18 February 1834, British Library MS Add.37188, fol. 212; V. Y. Bowditch, *Life and Correspondence of Henry Ingersoll Bowditch*, 2 vols. (Boston: Houghton, Mifflin, 1902), vol. 2, pp. 267–8; and Lardner to Babbage 29 March 1834, fol. 288. For Saxton and Watkins see I. R. Morus, *Frankenstein's Children: Electricity, Exhibition and Experiment in Early-Nineteenth-Century London* (Princeton: Princeton University Press, 1998), pp. 83–92. Bowditch was introduced to Babbage through his father, the eminent Boston mathematician Nathaniel Bowditch, actuary, nautical almanac-maker, and translator of Laplace: see Henry Bowditch to Nathaniel Bowditch, 13 December 1833, in Bowditch, *Life and Correspondence of Henry Ingersoll Bowditch*, vol. 1, pp. 68–9: 'How can one tell the effect which the examination of such a machine might produce upon the minds of some of our young and intelligent mechanics?'

21 Babbage to Milne, 1842; Milne to Babbage 5 June 1843; Milne to Babbage 20 July 1843, British Library MS Add.37192, fols. 224, 326, and 381; and A. Filipoupolitti, 'Premises for Exhibition and Use', *Museums History Journal*, 4 (2011), pp. 11–28, on p. 21.

22 Babbage, *Passages from the Life of a Philosopher*, 147–67; *International Exhibition of 1862: Illustrated Catalogue of the Industrial Department, British Division* (London: HM Commissioners, 1862), vol. 2, p. 46 (no. 3012); and L. Purbrick, 'The Dream Machine: Charles Babbage and His Imaginary Computers', *Journal of Design History*, 6 (1993), pp. 9–23, on p. 12. Gravatt also tried to assemble 'a number of separate parts' of the difference engine given him by Babbage: see Gravatt to Jelf (KCL Principal), 7 November 1861, British Library MS Add.37198 fol. 258.

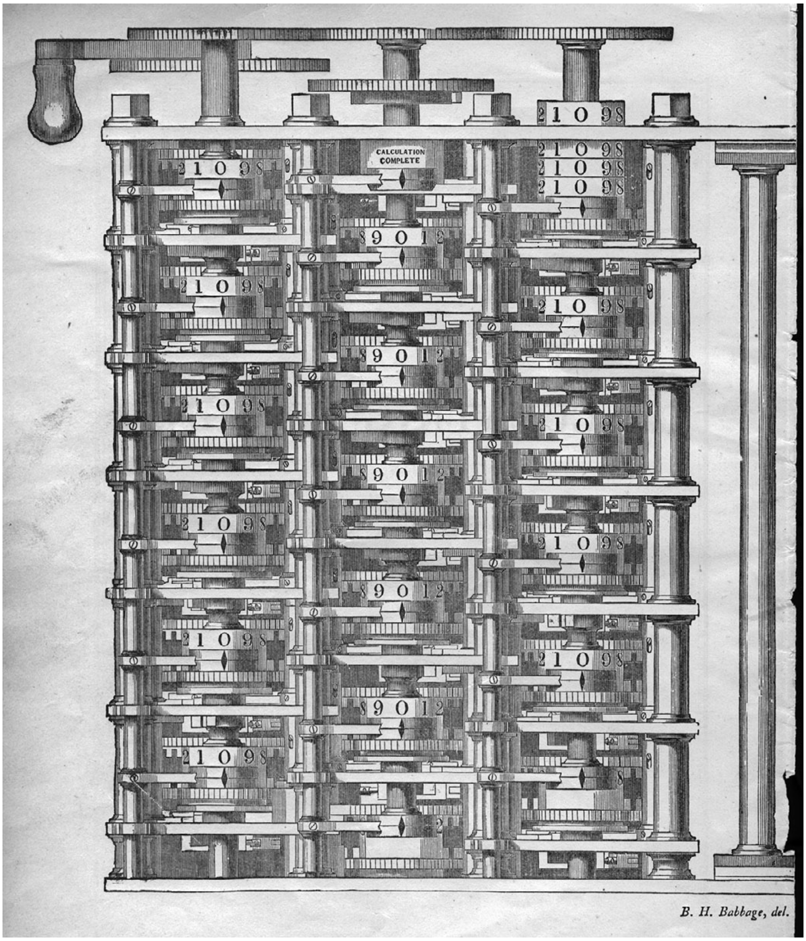

Figure 6.1 Benjamin Herschel Babbage's drawing of the fragment of the difference engine on show at South Kensington in 1872. From *Babbage's Calculating Machine or Difference Engine* (London: HMSO, 1872). Image © Whipple Museum (Wh.2339).

relic's three principal axes and number wheels, an image subsequently treated as the definitive rendering of the device (Figure 6.1). In 1876, under the aegis of the Devonshire Commission on scientific instruction, and its energetic secretary Norman Lockyer, once again a major exhibition was staged at South Kensington of both current and historic apparatus as a means to weld contemporary scientific hardware and education to the material memory of their development. The Babbage model, with its carriage mechanism and ambitious design given due attention as 'a machine for manufacturing tables', went on display and was occasionally put to work; and has stayed in South Kensington ever since.[23]

23 B. H. Babbage, *Babbage's Calculating Machine or Difference Engine* (London: HMSO, 1872); *Catalogue of the Special Loan Collection of Scientific Apparatus at the South Kensington Museum*, 3rd edn (London: Eyre and Spottiswoode, 1877),

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The repute of this machine, seemingly safely ensconced as an admirable memorial in its museum, has nevertheless somehow been destabilised by its apparent successor. As his scheme for the first difference engine foundered, Babbage projected a much more ambitious analytical engine, a general-purpose machine never fully to be completed, which demanded a 'store' in which operations and results to be performed by a 'mill' could be mechanically stashed and recovered when needed. In 1835 Babbage told Nathaniel Bowditch, Henry Ingersoll's father and pre-eminent Boston mathematician, that during carriage 'in the old Engine when addition takes place a memorandum is made' and 'the proper arms then pick up these memoranda in *succession*', while in 'the new Engine after addition all the carriages are affected at once (at the *same instant*) the engine *foreseeing* if necessary when a carriage will itself cause carriage to several nines above'. The difference engine's successive carriage would be replaced by a much faster anticipating carriage and thus an accelerated calculation mechanism. Memory must be complemented by foresight. The mechanical function of memory was geared to the capacity to know how to act ahead of time. He explained in his summary memorandum of late 1837 that, 'if the mechanism which carries could be made to *foresee* that its own carriage of a ten to the digit above ... would at the next step give notice of a new carriage, then a contrivance might be made by which, acting on that knowledge, it should effect both carriages at once'.[24]

The inspiration was the spatial layout of steam-driven textile works, with continuous throughput and stern labour discipline. Karl Marx's 1860s London writings on industrial capital used Babbage as key evidence that 'the factory is still described in English as a "mill"', and stated that 'Babbage treated large-scale industry from the standpoint of manufacture alone.' In his analysis of steam engineering and the factory system, Babbage explained that 'whenever the individual operation demanding little force for its own performance is to be

pp. 6–7 (no. 23); and R. Bud, 'Responding to Stories: The 1876 Loan Collection of Scientific Apparatus and the Science Museum', *Science Museum Group Journal*, 1 (spring 2014), http://dx.doi.org/10.15180/140104 (accessed 13 December 2018).

24 Babbage to Bowditch, 2 August 1835, in M. R. Williams, 'Babbage and Bowditch: A Transatlantic Connection', *Annals of the History of Computing*, 9 (1988), pp. 283–90, on p. 287 (stress in the original); and C. Babbage, 'On the Mathematical Powers of the Calculating Engine' (December 1837), in H. W. Buxton (ed.), *Memoir of the Life and Labours of the Late Charles Babbage*, ed. A. Hyman (Cambridge: MIT Press, 1988), p. 187 (stress in the original). See Ashworth, 'Memory, Efficiency and Symbolic Analysis', pp. 650–1.

multiplied in almost endless repetition, commensurate power is required'.[25] This multiplication of power, so evident in the interactions of steam technology and textile manufacture, required ordered control. Artisan skill, so it was intended, would be systematically disciplined and confined through reduction of degrees of freedom in the programmed operations of the engine. The 'beautiful contrivance' of pasteboard or metal cards used to manage a Jacquard loom provided both model and control system for the engine. Alongside store and mill, therefore, 'the Analytical Engine will possess a library of its own. Every set of cards once made will at any future time reproduce the calculations for which it was first arranged.'[26] The crucial innovation of the analytical engine was exactly this division of labour, prompted by the automation of the anticipatory system of carriage and of managerial reproduction and control, between the tasks of calculation in the mill and those of recall from the store and library.

Babbage turned this system of mechanical memory and anticipation into a moral cosmology. In a *Treatise* composed during his analytical engine project and tellingly subtitled 'a fragment', he meditated on the relation between memory, immortality, and fame. In a distinctly autobiographical passage, he foresaw 'the approaching dawn of that day' when 'more highly endowed' minds would 'exchange the hatred they experience from the honest and dishonest intolerance of their contemporaries for that higher homage, alike independent of space and of time, which their memory will forever receive'. It was not simply that in some millenarian future Babbage and his ilk would at last be rewarded with deserved memorials. Rather, 'memory seems to be the only faculty which must of necessity be preserved in order to render a future state possible'. The very existence of prospective punishment and reward depended on material preservation of individual memory. The designer of the difference and analytical engines had a candidate mechanism for memory preservation: the embodiment of voice and movement in air and water. Like the calculating engine, 'the air itself is one vast library', he argued, 'the never-failing historian of the sentiments we

25 K. Marx, *Capital: A Critique of Political Economy, Volume 1* (Harmondsworth: Penguin Books, 1976 [1867]), pp. 468–70; and C. Babbage, *On the Economy of Machinery and Manufactures*, 4th edn (London: Charles Knight, 1835), pp. 49–50. See M. Berg, *The Machinery Question and the Making of Political Economy 1815–1848* (Cambridge: Cambridge University Press, 1980), pp. 182–97.

26 Babbage, *Passages from the Life of a Philosopher*, p. 119.

have uttered'. Particles in motion worked like mechanical records in the engine, forever available to recall to presence the traces of past actions, 'the eternal witnesses of the acts we have done'.[27]

In Babbage's mix of tough materialism about the labour process and ruthless immaterialism about the dominance of thought over mechanics and of memory over time, the movement between factory, mind, and machine was explicit: 'the analogy between these acts and the operations of mind almost forced upon me the figurative employment of the same terms'.[28] Babbage himself may well have treated the relics of the machines as so many gifts, material fragments of his own memorable achievements and his aims at a legitimate afterlife. He presented fragments of the Difference Engine to his friend Harry Buxton, and other components of the machine survived in family possession, being handed on to Nevil Francis Babbage, Benjamin's great-great-grandson. The latter are now in the Macleay Museum at the University of Sydney, one of the largest surviving collections of machine components from the original project of the 1820s.[29] Babbage's calculating engines thus embodied mnemotechnics. They aimed at the economical mechanisation of memory and were caught up with mechanisms of the Victorian commemorative economy. They were at least at home in showrooms as workshops, while their notoriety within official memory long depended on cautionary parables about their failure ever to be completed, and the ironies of the subsequent histories of automatic computing they allegedly spawned.[30]

The Whipple Museum holds a remarkable segment of an addition and carry mechanism of a difference engine put together around 1879 (Figure 6.2), eight years after his father's death, by Babbage's

27 Babbage, *The Ninth Bridgewater Treatise*, pp. 54, 112; and Babbage, *Passages from the Life of a Philosopher*, p. 405. See J. Picker, *Victorian Soundscapes* (Oxford: Oxford University Press, 2003), pp. 15–17; and W. Schivelbusch, 'World Machines: The Steam Engine, the Railway and the Computer', *Log*, 33 (winter 2015), pp. 54–61, on p. 61.

28 Babbage, *Passages from the Life of a Philosopher*, p. 119; and Babbage, 'On the Mathematical Powers of the Calculating Engine', p. 216.

29 The Buxton material is at the Museum of the History of Science, Oxford, no. 94229. The Macleay Museum, University of Sydney, object no. 1993.3, holds the components presented by Nevil Francis Babbage. Thanks are due to Jude Philp at the Macleay Museum for her help.

30 D. Swade, *The Cogwheel Brain: Charles Babbage and the Quest to Build the First Computer* (London: Little, Brown, 2000), pp. 308–14; and Purbrick, 'The Dream Machine', pp. 14–20. For Babbage's own retrospection and reconstruction of his own role and repute, see M. Fisch, 'Babbage's Two Lives', *British Journal for the History of Science*, 47 (2014), pp. 95–118.

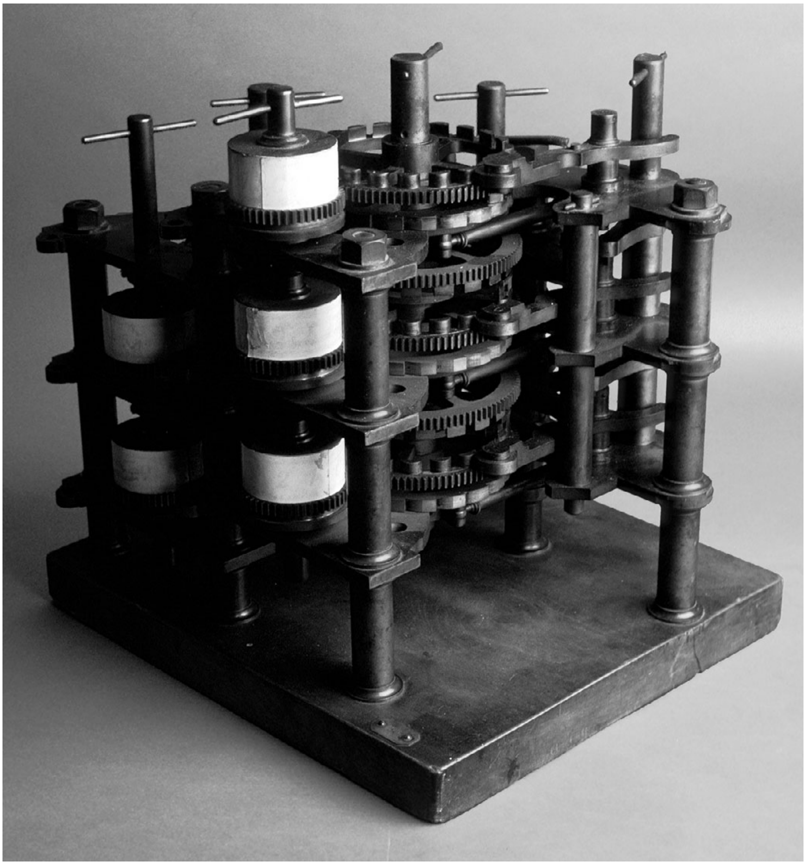

Figure 6.2 Demonstration model of a calculating segment of the difference engine with five cages assembled by Henry Prevost Babbage in Bromley in 1879 and sent to Cambridge in 1886. Image © Whipple Museum (Wh.2339).

youngest son Henry, a former Indian army officer. Not the only such model then assembled by Henry, it was almost certainly the largest, constructed from precisely machined components of brass, steel, and a nickel–copper alloy described as German silver. These were material relics of the original difference engine project managed by Babbage and Clement. They were accompanied by a brief sheet of instructions from Henry, together with his elder brother Benjamin's descriptive exhibition pamphlet. The Whipple Museum's device was sent to Cambridge in December 1886. It has a pair of principal columns set up to carry series of figures vertically on their axes, three squat cylinders on one and two on the other. These five metal rings, with digits marked on them, are now papered over. The rings were originally to be concealed by screens set up to hide unwanted digits, which 'require slight fitting'. Indeed, the expectation was that key components of the carefully boxed-up machine sent from Henry's Cheltenham retirement home would then be assembled in

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Cambridge. 'The German silver rings with the numerals engraved on them', he wrote, 'have been made recently and never fitted on.'[31]

The hand-turned axes interlock to perform addition by rotating the columns in series. The principle of such engines was that successive addition could generate the exact numerical values of the terms of a range of power series by the addition of a constant difference. They could also calculate terms of algebraic series such as logarithms where, though the differences were not constant, this inaccuracy could be ignored over large ranges of values. In such cases, Benjamin's pamphlet explained, 'the greater the number of difference columns that is worked out, the nearer a constant difference is approached'. This demonstration device also significantly exhibits the elegant carriage mechanism, a rudimentary version of its automated successive memory. The device has a supplementary axis through which, when a figure wheel travelled from nine to zero, numbers were to be sequentially carried over to the next column of digits after moving what, ever keen to move between machine and mind, Babbage called a warning lever. 'A warning of carriage will be heard when the carriage from the wheel below is being picked up, which warning will be followed almost immediately by the actual carriage on the wheel above.'[32]

As part of a long and obsessive campaign of filial piety and earnest technical enterprise, it might have seemed apt that Henry's gift went to Cambridge, where his father had been a precocious undergraduate (who nevertheless sat no examinations) and erstwhile professor (who gave no lectures). It was not the first token Henry gave the University in his father's memory. Back in May 1871, the new Cambridge professor of experimental physics, James Clerk Maxwell, then preoccupied with his *Theory of Heat*, set out to obtain a seventeenth-century Florentine glass thermometer that Charles Babbage had got from the director of the Florence museum, Vincenzo Antinori. When Charles died in autumn 1871, Henry at once contemplated transferring the instrument to Cambridge. 'Send the thermometer and letters to Professor Clerk Maxwell,' Henry was advised by his father's friend Frederick Pollock, lawyer and man of letters. Maxwell 'has charge of the collection of Philosophical Instruments, among which I apprehend it will be placed in the new building now about to be erected', the Cavendish Laboratory on

31 H. Babbage, Whipple Museum MS 2339, December 1886, sheet 3 ('note'). See the appendix to this chapter.

32 B. H. Babbage, *Babbage's Calculating Machine or Difference Engine*, p. 7.

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the New Museums Site. Babbage's thermometer reached Cambridge in summer 1872.[33]

It was in this collection of philosophical instruments, too, that Henry's model difference engine was housed from 1887. The recently appointed head of the Cavendish, J. J. Thomson, reported that, alongside the acquisition of the whole of Maxwell's scientific library, the laboratory had also been presented by Henry with 'a portion of the very interesting Difference Machine invented by his father'.[34] The model's home remained the New Museums site, tracing a pathway between university labs and their pedagogical exhibitions. Despite subsequent claims about the influence of Babbage's projects on the modern development of computation, Cambridge institutional memory of the 'very interesting machine' and its associations seems to have faded in the interim during the regimes of Thomson and his successor Ernest Rutherford. In 1936 the University's Mathematics Faculty Board backed the establishment of a Mathematical Laboratory for computing, in the wake of the construction of a Meccano version of a differential analyser for calculating molecular wave functions, prompted by the chemistry professor John Lennard-Jones and aided by the Manchester numerical analyst Douglas Hartree. Lennard-Jones was *pro tem* Laboratory director, and the Cavendish researcher Maurice Wilkes was charged with working on the proposed machines. Wartime mobilisation halted university plans while intensifying state and industrial investment in automatic computation. Only in autumn 1946 was Wilkes at last placed at the head of the Mathematics Laboratory, based on the eastern side of the New Museums Site, with computer research as his

33 Maxwell to Tait, 25 and 27 May 1871, in *The Scientific Letters and Papers of James Clerk Maxwell*, ed. P. M. Harman (Cambridge: Cambridge University Press, 1995), vol. 2, pp. 645, 648; Pollock to Henry Babbage, 17 July 1872, British Library MS Add.37199, fol. 576; Henry Babbage to Power, 7 August 1872, fol. 581; and J. C. Maxwell, 'Report on the Cavendish Laboratory', 14 April 1875, in *The Scientific Letters and Papers of James Clerk Maxwell*, ed. P. M. Harman (Cambridge: Cambridge University Press, 2002), vol. 3, p. 213. This thermometer now resides in the Whipple Museum, accession no. Wh.1116.

34 J. J. Thomson, 'Experimental Physics', in 'Museums and Lecture Syndicate Annual Report for 1886', *Cambridge University Reporter*, no. 688 (26 May 1887), p. 749. For the role of historical instruments and collections in the early Cavendish Laboratory projects see B. Jardine, 'The Museum in the Lab: Historical Practice in the Experimental Sciences at Cambridge, 1874–1936', in B. Jardine, E. Kowal, and J. Bangham (eds.), *How Collections End: Objects, Meaning and Loss in Laboratories and Museums*, BJHS Themes Vol. 3 (Cambridge: Cambridge University Press and British Society for the History of Science, 2019).

brief, and his ally Hartree as the new Cambridge mathematical physics professor.[35]

That same autumn an explosive argument erupted in the correspondence columns of *The Times*, provoked in part by publicity given a speech by Lord Mountbatten as president of the Institution of Radio Engineers. The speech was a response to Alan Turing's work on automatic computers, which the noble Admiral, soon to become the very last Viceroy of India, reckoned showed it possible 'to evolve an electronic brain'. Hartree wrote from the Cavendish to protest against Mountbatten's phrase, explaining that while such devices, even purely mechanical ones, might exercise a form of judgment, this was 'no substitute for thought', the prerogative of human operators. At this point in November 1946 the polymathic Rupert Gould, naval officer, horologist, and broadcaster, intervened to refresh *The Times* readers' memories of Charles Babbage's analytical engine, a mechanical device capable, as Gould put it, of 'memorizing in its store for future use the results of its calculations'.[36]

It was Gould's letter that prompted Hartree to consult Babbage's autobiography in which he learnt at last of the nineteenth-century mathematician's doctrines about the mechanisation of judgment and memory. Wilkes remembered Hartree delightedly passing round a copy of Babbage's book in the Mathematics Laboratory. Hartree published a summary of the analytical engine project in 1949, while Wilkes himself went to South Kensington to consult the Babbage notebooks Henry Babbage had given to the Science Museum. It was thanks to Hartree that Henry's difference engine model fragment held at the Cavendish was then remembered, and moved in about 1950 from west to east across the site to the Mathematics Laboratory, where Wilkes used it to lecture on the principles of automatic addition.[37] Wilkes recalled that at that point 'an object of this sort was not so highly regarded', and could scarcely be seen as 'epoch-making' in comparison with the analytical engine. This was a period of intense interest in automatic memory and the psychological and

35 M. Croarken, 'The Emergence of Computing Science Research and Teaching at Cambridge, 1936–1949', *Annals of the History of Computing*, 14 (1992), pp. 10–15.

36 A. Hodges, *Alan Turing: The Enigma* (London: Vintage, 1992), p. 347; D. Hartree, 'The electronic brain: a misleading term', *The Times*, 7 November 1946, p. 5; D. Hartree, 'The electronic brain', *The Times*, 22 November 1946, p. 5; and R. Gould, 'The electronic brain', *The Times*, 29 November 1946, p. 5.

37 M. V. Wilkes, *Memoirs of a Computer Pioneer* (Cambridge: MIT Press, 1985), pp. 195–9; D. Hartree, *Calculating Instruments and Machines* (Urbana: Illinois University Press, 1949), pp. 69–72; and Cohen, 'Babbage and Aiken', p. 189.

moral implications of recall and mechanisation. Even if the difference engine model was not 'epoch-making', it nevertheless went on show at the Science Museum's 1976 exhibition 'Computers Then and Now', after which, through the lobbying of the Whipple curator David Bryden, who noted his Museum's possession of other 'Cambridge firsts' in the history of calculating instruments such as Oughtred's circle of proportion, it was deposited in the Whipple. In 1980 Wilkes also passed Henry's accompanying notes and Benjamin Herschel Babbage's pamphlet to the Museum.[38]

It is thus uncharacteristically appropriate that the Babbage fragment is held on the Cambridge site and put on public show there – the location and display are congruent with the artefact's original purpose as demonstration model and its lengthy afterlife. Henry Babbage's commemorative enterprise incorporated laborious manufacture of a range of models; significant publicity initiatives; and the systematic distribution of material mementos, somewhat akin to the actions of traditional impresarios of saintly relics.[39] This enterprise of assemblage and display was thus never entirely a fanciful vision of a dimly predictable future in which the calculating engines would at last occupy their proper place; rather, it was a deliberate exploitation of a highly crafted past, bringing souvenirs of artisan workshops and hardware of the Age of Reform back to life amidst the pomp and circumstance of Victorian *fin-de-siècle* shows and salons. For Babbage, memory was precisely a moral and material assemblage of traces and relics that somehow might survive, despite their transience and fragility.[40] The Whipple fragment is thus aptly and tenuously positioned between uncertain afterlife and patriarchal provenance. It was as much pious resuscitation as prophetic vision.

Embodied in that fragment is a complex and telling relation between memories of Henry's upbringing and the labour relations of the engines' manufacture under his father's direction. 'Now what

38 Bryden to Wilkes, 1 March 1977 and Wilkes to Bryden, 4 March 1977, Whipple Museum Archive file P 009 and 011. Thanks to Joshua Nall for these materials. For the technoscience of automatic memory in the 1950s through the 1970s see A. Winter, *Memory: Fragments of a Modern History* (Chicago: University of Chicago Press, 2012).

39 P. Geary, 'Sacred Commodities', in A. Appadurai (ed.), *The Social Life of Things* (Cambridge: Cambridge University Press, 1986), pp. 169–92; S. Stewart, *On Longing: Narratives of the Miniature, the Gigantic, the Souvenir, the Collection* (Durham: Duke University Press, 1993), pp. 133–9; and A. Walsham, 'Relics and Remains', *Past and Present*, supplement 5 (2010), pp. 9–36, on pp. 31–2.

40 Fisch, 'Babbage's Two Lives', pp. 115–16 on the artifice and tragedy of Babbage's memory.

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was your first serious mistake in life, Henry?', Charles allegedly once asked his son. 'I answered on the instant, "Alas, my choice of a parent!"' Up to his enrollment at University College London in 1840–2, Henry lived with his paternal grandmother Elizabeth on Devonshire Street in Marylebone, rather than round the corner at his father's house and workshop in Dorset Street. 'I feared him, and often left the house to avoid meeting him.'[41] Encounters were almost entirely mediated through the labours of the workshop and the showmanship of Babbage's fashionable soirées. The difference engine had by this time become a party piece for display to prestigious visitors at Dorset Street, where its tricks of automated memory and foresight would be used to telling effect. Charles also made the young UCL student come to his drawing office two or three times a week, where he was taught to 'handle tools and to draw machinery'. After leaving college in summer 1842, Henry spent several days a week in the workshops, training with the Lambeth engineer William Garton in lathe-work, metal forging and 'a little hardening and tempering steel'. He also studied mechanical drawing, 'such as clock work', with Jarvis, who 'made all the beautiful drawings for the analytical engine and knew something of mathematics'.[42]

These same months, while Henry encountered the collective and individual skills on which the engine enterprise depended, also saw the termination of the difference engine project, damned by the Astronomer Royal George Airy and axed by Robert Peel's government in November 1842 on grounds of cost, and the inauguration the next year of the machine's display at King's College London. 'It is amazing', Henry later reminisced, that the government 'did not see the advisability of having the calculating part completed. A few hundred pounds would probably have been sufficient for this . . . a Difference Engine might have existed.'[43] As was common in Henry's cohort of engineers and servicemen, and true of both his elder brothers, colonial employment eventually provided a career. By the end of 1842 it had been decided Henry would enter the East India Company military under the patronage of his father's friend William

41 H. Babbage, *Memoirs and Correspondence*, p. 93.

42 H. Babbage, *Memoirs and Correspondence*, pp. 9–11. Henry mentions 'a workman called Garton'; William Garton, engineer, is listed in the 1841 census at Anderson's Walk, Lambeth, then aged fifty, with son Charles, apprentice tool-cutter.

43 H. Babbage, 'Conclusion' (1888), in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), pp. 339–42, on p. 340. For Airy's role see Swade, *The Cogwheel Brain*, pp. 134–54.

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Plowden, one of the Directors. He left for India, at the age of eighteen, in spring 1843. Seven decades later, memory of cool separation stayed vivid: 'my father bade me good-bye in his library at 1 Dorset Street. He did not see me into the cab.'[44]

Henry's early Indian service was a characteristic Company combination of strenuous disciplinary training and intense if irregular violence. He was rapidly promoted Lieutenant in the Bengal Infantry, studied Hindi and Bengali, and became an interpreter. He led fighting both in the vicious Company war with Sikh forces in the Punjab in 1846 and in military raids in Assam against the Adi hill peoples in 1848, aggression which, Henry long remembered, taught the value of well-armed punitive expeditions rather than any attempt at permanent fortified settlement along the imperial frontiers.[45] He married the much younger Irishwoman Mary Bradshawe, nicknamed Min, whose father, an officer in the Company's army, had allegedly been poisoned with diamond dust on the orders of the ruler of Awadh. Henry returned to London on leave in 1854–6. The thirty-year-old military veteran and family man, accompanied by wife, baby daughter, and Indian nurse, engaged in a period of committed work and transformation in his relations with his father and the calculating engines. Decisively, Henry and his family settled at his father's house in Dorset Street. Charles installed a mirror in the dining room 'so that he could see Min in the glass without looking in her direction'. Henry reflected that 'I met him on more equal terms . . . the wish to merit his approval since I had grown up had always been a strong motive with me, but was now strengthened and endured to the end.'[46]

This was a period of intense labour. Henry worked on mathematics, cryptography, and practical arts such as photography and electroplating; he joined his father on exhibition tours and visits to engineering sites such as Isambard Brunel's *Great Eastern*. It also coincided with important developments in the calculating engine projects, in the wake of the Great Exhibition and the polemics and

44 H. Babbage, *Memoirs and Correspondence*, 11–12. Charles Babbage recalls obtaining Henry's East India Company place through Plowden, in Babbage to Alexander Dallas Bache, 8 August 1854, Yale University Bienecke Library General MSS 1322, box 1, folder 4. Thanks are due to Alexi Baker for this source. For the difference engine's transfer to King's College see Milne to Babbage, 5 June 1843, British Library MS Add.37192, fol. 326.

45 H. Babbage, 'Expeditions against the Abors', *The Times*, 24 March 1894, p. 10; and H. Babbage, 'The operations in 1848', *The Times*, 15 September 1911, p. 3.

46 H. Babbage, *Memoirs and Correspondence*, p. 94.

publicity raised about new engineering and its capital effects. In summer 1852 Charles Babbage had sought unsuccessfully to get government funds and engineers' commitment for a second, more efficient version of the difference engine.[47] At the same time, William Farr vainly proposed that Babbage's difference engine be used to verify joint life tables for his General Register Office. Babbage also began negotiating with former Clement employee Whitworth, now the pre-eminent Manchester engineering master. Whitworth's repute as manufacturer of machine tools had been established at the 1851 Great Exhibition and marked in the notorious engineers' lockout against his own workforce over union demands to abolish piece-work and against deskilling the following year. In summer 1855 Whitworth began abortive discussions with Babbage about constructing some version of the analytical engine, the ultimate embodiment of automatic skill.[48]

Meanwhile, the Swedish printers Georg Scheutz and his son Edvard brought to London their own version of a difference engine, inspired by Lardner's earlier accounts of Babbage's machine. They visited Charles and Henry at Dorset Street over two days in November 1854, and with the aid of Babbage and his engineer colleague Gravatt began to publicise their device for computing and printing mathematical tables with a bronze framed machine on a steel base plate and silver-plated number wheels with figures engraved in black enamel. The engine was praised for its simplicity, its cheapness, and because 'it can easily be taken to pieces and examined if need be'.[49] Eventually, the government took the Swedish engine for Farr's Office, though by the 1870s Charles Thomas de Colmar's arithmometer, a device whose repute was also established through successive industrial and technical exhibitions, was beginning to displace the grander Scheutz device. Both for the French machine and for the Swedish one, issues of labour skill and reliability were decisive. Farr refused to put the Scheutz machine on show at South Kensington in 1862 alongside Babbage's difference engine, since 'its work had to be

47 H. Babbage, *Memoirs and Correspondence*, pp. 80–3; and Babbage, *Passages from the Life of a Philosopher*, pp. 100–107.

48 Farr to Babbage, 2 September 1852, British Library MS Add.37195, fol. 135; A. Hyman, *Charles Babbage: Pioneer of the Computer* (Oxford: Oxford University Press, 1982), p. 231; and Atkinson, *Sir Joseph Whitworth, the World's Best Mechanician*, pp. 172–90.

49 M. Lindgren, *Glory and Failure: The Difference Engines of Johann Müller, Charles Babbage and Georg and Edvard Scheutz* (Cambridge: MIT Press, 1990), pp. 184–92; and H. Babbage, *Memoirs and Correspondence*, p. 83.

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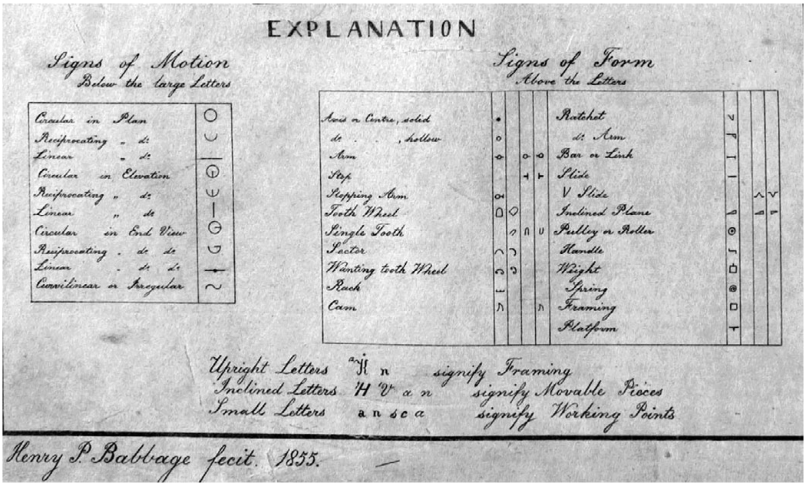

Figure 6.3 Henry Babbage's explanation of the mechanical notation of the Scheutz engine, drawn in London in summer 1855. By permission of the Science and Society Picture Library (Science Museum Library MSR/0012).

watched with anxiety and its arithmetical music had to be elicited by frequent tuning and skilful handling'. He insisted that 'it consists of a multitude of pieces and some of these occasionally get deranged . . . it is not infallible, except in very skilful hands'.[50]

Because of such ineffable skill and dangers of showmanship, the scheme designed by the Swedish father and son had somehow to be rendered legible to its audience so as to be successfully marketed to the British state. It seemed important to display the distinction between Babbage's difference engines and the Scheutz layout, especially its carriage mechanism, which adopted a completely contrasting mode of automatic memory. Babbage worked closely with his own son, Henry, to achieve this legibility. In spring 1855 Henry trained himself in copying the technical notation of the mechanical drawings for his father's second version of the difference engine, distracted somewhat briefly by the birth of a son in late March. Then he was taken to Somerset House to inspect the Swedish version, and applied the same mechanical notation to this new machine (Figure 6.3). His vast diagrams of gear and wheel trains, ranging from eight to over thirteen feet in length, were pasted onto calico sheets at Dorset Street by Min, Henry, and Charles. 'They were really a work of art and would have done credit to a professional draughtsman,' Henry boasted. Somewhat to Henry's surprise, his father treated commodification literally, and formally bought the drawings

50 Farr, *English Life Table*, pp. cxl–ii; and Lindgren, *Glory and Failure*, pp. 216, 224–5, 285. For the arithmometer see S. Johnston, 'Making the Arithmometer Count', *Bulletin of the Scientific Instrument Society*, 52 (1997), pp. 12–21.

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from him for £50, even though 'I always intended them for him, and considered them his.'[51]

The mechanical notation helped make Henry's repute as a draftsman of memory, however transiently. He went to the British Association at Glasgow in September 1855 to lecture on the notation's panoptic virtues: 'we can demonstrate the practicability of any contrivance and the certainty of all its parts working in unison *before a single part of it is made*'. Thus not only had the language of signs in some way compensated for the labour and financial uncertainties that plagued the engine-construction projects, but Henry's paperwork had become an integral part of the substitution of mechanism for weak memory: 'it would be beyond the powers of the human mind to master and retain the details of the complicated machinery'. At just the same time, at the Clydeside shipyard where the *Great Eastern*'s paddle shaft was being forged, Henry witnessed the power of controlled machinery and labour on metal: 'masses of about two tons were welded in one operation under the blows of a steam hammer'. The family inheritance of embodied skill in manufacturing paper imagery became part of their domestic and industrial legacy. Charles and Henry took the drawings to the Institution of Civil Engineers in Westminster, insisting that the notation allowed even 'the most fleeting movements' to be captured forever. 'It had, as it were, *photographed the footsteps of time*', Charles told the Civils; 'it had conferred fixity and permanence on the swiftest motion.'[52]

Alongside the inscription system that would somehow make the engine's functions visible and permanent, at the very same moment in late 1855 Charles and Henry also tried an experiment in model building to illuminate the carriage and addition mechanisms in the Dorset Street difference engine and help establish their independence and originality. From the workshop stores they 'fitted and selected' five sets of number wheels and gears for their model. Henry 'cleaned them up and did what was necessary, and put them together, two cages in one column and three cages in the other

51 H. Babbage, *Memoirs and Correspondence*, pp. 85–6; and H. Babbage, 'Conclusion', p. 341.

52 H. Babbage, 'On Mechanical Notation as Exemplified in the Swedish Calculating Machine of Messrs. Scheutz' (1855), in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), pp. 246–7, on p. 246 (my stress); C. Babbage, 'Scheutz's Difference Engine and Babbage's Notation' (1856), in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), pp. 248–57, on p. 257 (my stress); H. Babbage, *Memoirs and Correspondence*, pp. 87, 89; and Lindgren, *Glory and Failure*, p. 192.

column'. Over a few weeks Henry learnt how to work the mechanism for carriage by hand. Significantly, this was precisely the same layout of three wheels on one column and two on the other as was also evident in the Whipple Museum's model engine, built almost a quarter of a century later. In 1856 Henry and Min returned to India and the violent crisis of the first Indian war of independence, leaving children, drawings, and the new demonstration model as part of the paternal inheritance. Over a century later, Maurice Wilkes was so struck by this episode in the history of the machines and the family that he turned it into a play, performed as a Christmas entertainment in 1982 at Boston's Computer Museum.[53]

Embodiment is also expropriation: to claim that what was fixed in metal's body was pure intellect was to assert the primacy of the sole inventor's abstract thought. Charles Babbage unambiguously connected his authority to determine the calculating engine's legacy with the claims of pure reason over mere artisan labour and brute engineering. During the fight with Clement, Babbage told the erstwhile Prime Minister, the Duke of Wellington, that 'my right to dispose as I will of such inventions cannot be contested, it is more sacred in its nature than any hereditary or acquired property, for they are the absolute creations of my own mind'.[54] Yet the ailing Charles had made no disposition for the engines' fate as hereditary property when Henry again returned from India in spring 1871. It was only a few days before Charles's death in October 1871, with advice from his brother-in-law, the senior Indian lawyer Edward Ryan, that he drew up a will leaving Henry 'for his own absolute use and disposal his calculating machines and the machinery, tools, models and drawings of every kind relating thereto and all the contents and materials of his work-rooms'.[55]

53 H. Babbage, *Memoirs and Correspondence*, pp. 88–9. See M. V. Wilkes, 'Pray Mr Babbage: A Character Study in Dramatic Form', *Annals of the History of Computing*, 13 (1991), pp. 147–54; and [Boston] *Computer Museum Report* (Spring 1983), p. 15.

54 Babbage to Wellington, 23 December 1834, British Library MS Add.37188, fol. 525; and Hyman, *Charles Babbage*, 134. In September 1838 it was reported from the Newcastle BAAS by the Harvard lawyer Charles Sumner that Babbage planned to build the analytical engine in the United States, even though Sumner reckoned 'our Government . . . would no more give that sum for that purpose than keep a hunting pack of hounds': Sumner to Henry Bowditch, 28 September 1838, in Bowditch, *Life and Correspondence of Henry Ingersoll Bowditch*, vol. 1, p. 109.

55 H. Babbage, *Memoirs and Correspondence*, p. 181; the provisions of the will are printed in the *Pall Mall Gazette*, no. 2134 (15 December 1871), p. 7.

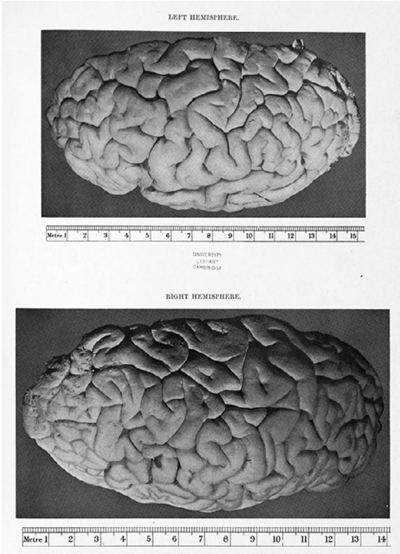

Figure 6.4 Charles Babbage's brain, presented to the Hunterian Museum by Henry Babbage in October 1871. From Victor Horsley, 'Description of the Brain of Mr Charles Babbage', *Philosophical Transactions of the Royal Society,* series B, **200** (1909), pp. 117–31, plate 9. Image courtesy of Cambridge University Library.

Henry took his father's cerebral and material powers very seriously, believing them worthy of posthumous show. The terminology of intellectual labour was then rapidly changing: in 1871 novelists invented 'brainwork' and psychical researchers started investigating 'brain-waves'; in a lecture on 'body and mind' in 1874 the UCL mathematics professor William Clifford argued that humans were simply conscious automata; from 1877 the *Brain* got its own eponymous journal; and in 1878 Clifford's ally Joseph Hooker used the term 'brain-power', while the author of a text on *The Hygiene of Brain and Nerves* began referring to 'brain-workers'.[56] The day following his father's death, Henry arranged for Charles's brain to be deposited and preserved in the Hunterian Museum at the Royal College of Surgeons (Figure 6.4). This was a public experiment on Babbage's doctrine of the materiality of the afterlife. The specimen was not to be anonymised: 'his character is known by his deeds and his published works and the brain should be known as his'; and it was to be understood as a paternal gift: 'I have but one standard to guide me, my thoughts of what could be the judgment of my father.' A few weeks later Henry sent the Royal College his father's portrait to accompany the brain.[57]

56 *Oxford English Dictionary*, 3rd edn (2011), s.v. 'brain'.

57 Henry Babbage to Paget, 19 October 1871, Archives of the Museum of the Royal College of Surgeons, Letters Book, cited in J. Agar, 'Bodies, Machines and Noise', in I. R. Morus (ed.), *Bodies/Machines* (Berg: Oxford, 2002),

The commemorative bequests launched the campaign to embody Charles Babbage's 'absolute creations' in metal. Henry spent much of 1872–3 settling his father's affairs. His initial aims were to write Charles's biography and to construct 'the Mill or actual working part of the Analytical complete in metal'.[58] Commemoration, politics, and engineering were entwined. In May 1872 Henry took his family to hear Clifford deliver a Royal Institution lecture in Babbage's memory. The young mathematician and evolutionist spoke on the plans for the difference and analytical engines, foresaw their completion when 'machines must be made all over the country', and explained how Babbage's life had become 'embodied in [his] workshop'. He also devoted a section of his lecture to Babbage's doctrines of foresight and immortality, the mechanical means through which apparent miracles could be programmed into the machine by its designer, and through which the traces of past actions could be materially preserved. All this, Clifford urged, showed the 'deeper law' of 'evolution as the true statement of the world's history'. Henry admired Clifford's enthusiasm about the analytical engine, but did not think he put enough stress on Charles's views about 'the never ending effects of our words and actions'. His father's doctrine of immortality was fundamental for Henry: an extant copy of the 1837 *Treatise* in which these views were developed still has Henry's annotations insisting on the scientific significance of such a view of memory and a future state.[59] Reminiscence and foresight were commonplaces in testimonies to Babbage's legacy. In his eulogy to Babbage at the Statistical Society of London, William Farr prophesied the completion of the analytical engine to calculate 'those still more complicated coefficients and variables which, it is easy to foresee, will be in requisition when future State problems are dealt with scientifically by *a political Newton*'. Henry promised Farr in January 1872 that he would indeed finish a working section of the

pp. 197–220, 297, 215; and Paget to Henry Babbage, 12 January 1872, British Library MS Add.37199, fol. 574.

58 Henry Babbage to Pollock, 8 January 1872, British Library MS Add.37199, fol. 558.

59 'Professor Clifford's notes for his lecture', in Lucy Clifford to Henry Babbage, 26 July 1879, University Library Cambridge MS Add.8705 no. 33; and H. Babbage, *Memoirs and Correspondence*, p. 184. Henry's copy of the *Treatise* is Harvard University Houghton Library *74 434: see Picker, *Victorian Soundscapes*, 158 n. 7. For Clifford's views see S. Cook, *The Intellectual Foundations of Alfred Marshall's Economic Science* (Cambridge: Cambridge University Press, 2006), pp. 189–91.

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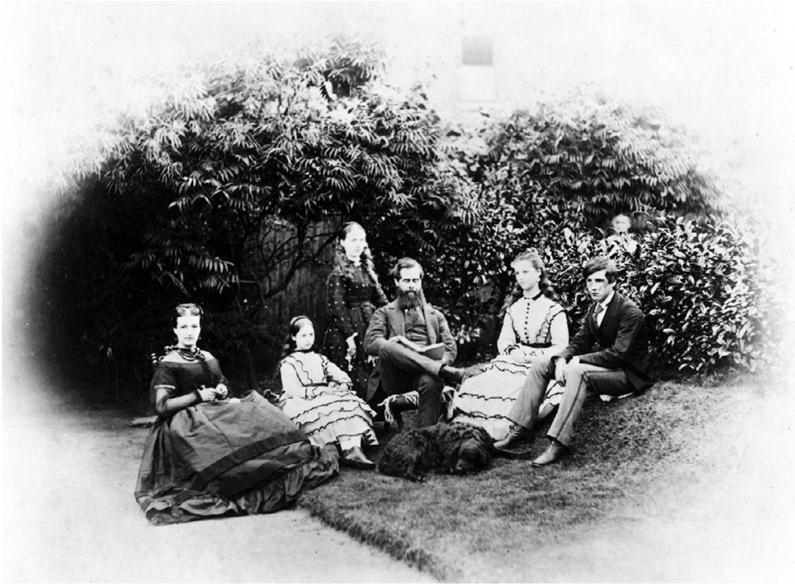

Figure 6.5 The Babbage family in the early 1870s: (from the left) Mary (Min), Sophie (b. 1860), Mary (b. 1857), Henry, Georgiana (b. 1852), and Harry (b. 1855). By permission of the Science and Society Picture Library (SSPL 10300411).

great engine, 'sufficient to perform those calculations which from their unmanageable extent baffle human skill'.[60]

In the event, it was the construction of the analytical engine's mill that would prove baffling and almost unmanageable. Henry made a brave start, hoping to finish the Mill to tabulate the reciprocal of π (defined as 7/22) to twenty-five significant figures. During 1872 he completed a set of drawings of the design; retained the services of the elderly engineer Richard Wright, whose four decades' experience on the calculating engines might prove invaluable; hired a new workman named Dancaster to 'push on the machine work'; commissioned a new workshop and house in suburban Bromley; and sold the house at Dorset Street. Almost all the equipment there was auctioned off: forges, fly presses, lathes, steam engines, and metal scrap. Henry retained but a little hardware for his own enterprise: 'a lathe or two, a small planing machine and some smaller tools'. These plans in place, he then returned to India for a final two years of military service and promotion to Major-General, setting up permanently back in England from early 1875 (Figure 6.5).[61]

60 W. Farr, 'Inaugural Address', 21 November 1871, *Journal of the Statistical Society of London*, 34 (December 1871), pp. 409–23, on p. 415 (my emphasis); and Henry Babbage to Farr, 20 January 1872, British Library MS Add.37199, fol. 564.

61 H. Babbage, *Memoirs and Correspondence*, pp. 183–4; and Fuller, Horsey, Son & Co., *Catalogue of a Collection of Engineers' Tools and Plant Used by the Late Mr Babbage* (1 March 1872), Erwin Tomash Library B65, Charles Babbage Institute, University of Minnesota.

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Henry was committed to his ultimate ambitious goal, the analytical mill. In early 1878 he compiled detailed manuscript notes on the best method for using the mill to compute the powers of the reciprocal of π by experimental methods using cross-multiplication, and in 1880 organised the casting of the mill's frame plates, 'not as part of the larger machine which my father proposed but something which would be practically useful by itself in the hands of a skilled operator'.[62] At the same time, with Henry's assistance and spurred by Farr's arguments, a British Association committee led by Clifford and managed by the civil servant Charles Merrifield considered the feasibility of completing the analytical engine, this 'marvel of mechanical ingenuity and resource'. They expressed understandable scepticism about the analytical plan, wondering 'until it leaves the inventor's hands in the finished state whether it really represents what is meant to be rendered in metal'; and they reported that by 1878 the analytical engine, designed to demonstrate the principle of anticipation, existed only as a series of gunmetal wheels and cranks on steel shafts, though to keep costs down most had been pressure-moulded in zinc-hardened pewter. At all events, despite the considerable possible utility of such an engine, the committee calculated its construction would cost up to £40,000 (£4,000,000 in modern terms), apparently a prohibitive sum, though perhaps some limited component might be built as 'a simple multiplying machine'. The mathematicians also cautioned that in cases of calculation by finite differences the 'specialization of the difference engine would probably give it an advantage over the more powerful engine'.[63]

Henry did not dissent from this somewhat frosty judgment – but his interests were subtly different, less concerned with precise calculations of the engines' future viability, more focused on commemorative vindication of paternal and mechanical virtues. The BAAS mathematicians dwelt on the fundamental principle of digital, or what they called 'discontinuous', machines, which they associated with the mechanism of 'millwork and clockwork'.[64] Henry certainly shared their interest in the economic and material distinctions

62 H. Babbage, 'Computations of the powers of π', University Library Cambridge MS Add.8705 no. 34 (entries dated January 1878); and H. Babbage, 'Babbage's Analytical Engine', p. 518.

63 C. Merrifield, 'Report of the Committee Appointed to Consider the Advisability of Constructing Mr Babbage's Analytical Machine' (1878), in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), pp. 323–30. Clifford's lead role in the committee is mentioned in Henry Babbage, *Memoirs and Correspondence*, p. 184.

64 Merrifield, 'Report of the Committee Appointed to Consider the Advisability of Constructing Mr Babbage's Analytical Machine', p. 323.

between continuous and discontinuous calculating devices. This concern emerged dramatically in his attack on a lecture given to the Institution of Civil Engineers by the new Liverpool engineering professor Henry Selby Hele-Shaw, who praised mechanical integrators and harmonic analysers, analogue devices that continuously traced the surfaces of areas to be computed 'in a way that could not be effected by mere trains of wheel-work, such as form the mechanism of some kinds of calculating machines'.[65] The professor's higher valuation of planimeters and mechanical integrators and his implied dismissal of the difference and analytical engines' wheelwork enraged Henry: in his father's calculating machines 'there was absolute accuracy of result, and the same with all operators, and there were mechanical means for correcting, to a certain extent, slackness of the machinery'. His memory of the calculating engines and their mastery of mechanical memory showed 'all except the simplest planimeters would become obsolete'. Hele-Shaw responded in kind: 'all efforts to employ mere combinations of trains of wheelwork for such operations as were required in continuous integrators had hitherto entirely failed', he claimed. The exchange about the virtues of discontinuous devices showed Henry how crucial it was to resuscitate the repute of Babbage's versions of the calculating engines.[66]

The conflict with the engineers took place after Henry had spent ten years at his Bromley house and workshop from 1875, during which he set out to publicise and, if possible, model the components of the simpler difference engine using his Dorset Street inheritance. He set out to combine the 'waste metal' left by his father with the museum machine on public show described in Benjamin's recent pamphlet. 'There was nearly, if not all of the Difference Engine . . . enough to put together the calculating part of the machine.' What was missing were gears and frame plates, many of which had been cut up for his father's experiments. Henry commissioned new frame plates as well as 'a new driving gear which answered perfectly'.[67] He sought to use the north London instrument-maker Robert William Munro, head of a prestigious engineering firm then building printing machines for the Bank of England and harmonic analysers, efficient examples of continuous integrators, designed by the eminent Glasgow professor William

65 Henry Hele-Shaw, 'Mechanical Integrators', *Minutes of the Institution of Civil Engineers*, 82 (1885), pp. 75–143, on pp. 76–7.

66 'Correspondence', *Minutes of the Institution of Civil Engineers*, 82 (1885), pp. 163–4.

67 H. Babbage, *Memoirs and Correspondence*, pp. 224–5; and H. Babbage, 'Babbage's Analytical Engine', p. 518.

Thomson for the Meteorological Office.[68] Henry's own memories of what happened next are confused, but are at least consistent in recording that in the 1870s he soon decided the project of building the difference engine's entire calculating section was beyond his limited means and those of his collaborators and peremptorily 'sent the whole to the melting pot'. He also learnt 'about the same time' of the destruction of the relics of the engine project held by Clement. Henry's reminiscences differ about whether he heard of Clement's workshop's burnt offering *after* he'd destroyed most of his own difference engine components, which would then be a tragic decision to be regretted ('I might have kept what I had'). Or perhaps he learnt of the fate of Clement's workshop *beforehand*, in which case his own metallurgical meltdown was apt ('I decided to dismantle the work'). Whatever the reliability of his memory, Henry's enterprise was decidedly backward-looking. 'I still hold to the opinion that the calculating part of the difference engine might have been completed at the time the Government gave it up for £500.'[69]

From then on, the difference engine was unambiguously consigned to history. This was a history with a melancholy moral. The Babbages' family friend Frederick Pollock, who had advised on the despatch of Babbage's thermometer to Cambridge, reminisced after a visit to Dorset Street that 'it was a strange fortune for a man to have eclipsed himself, as it were, in this way, and the deserted work benches, lathe and tools presented a dreary and melancholy spectacle'. The brilliant mathematician and patent lawyer John Fletcher Moulton recalled a visit there in May 1869 as 'one of the sad memories of my life'. Commenting on the Merrifield report, Moulton added that 'not only had [Babbage] constructed no machine, but the verdict of a jury of kind and sympathetic scientific men who were deputed to pronounce upon what he had left behind him either in papers or mechanism was that everything was too incomplete to be capable of being put to any useful purpose'.[70] Henry also often adopted the same tone in his own

68 H. Babbage, 'Computations of the powers of π' (entries dated August 1895). For Munro see https://collection.sciencemuseum.org.uk/people/ap26820/r-w-munro-ltd (accessed 2 March 2018).

69 H. Babbage, *Memoirs and Correspondence*, pp. 224–5; H. Babbage, 'Babbage's Analytical Engine', p. 518; H. Babbage, 'Conclusion', p. 341; and H. Babbage, 'Computations of the powers of π' (entries dated August 1895). See Cohen, 'Babbage and Aiken', p. 187; and Swade, *The Cogwheel Brain*, p. 316.

70 F. Pollock, *Personal Remembrances*, 2 vols. (London: Macmillan, 1887), vol. 2, pp. 9, 206; and J. F. Moulton, 'The Invention of Logarithms, Its Genesis and Growth', in C. G. Knott (ed.), *Napier Tercentenary Memorial Volume* (London: Longmans, Green, 1915), pp. 1–32, on pp. 19–20. See G. Williams, 'Engine

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memoirs. He told the British Association that this history 'is sufficient to damp the ardour of a dozen enthusiasts', and added in his entry on calculating machines for *Chambers's Encyclopaedia* that 'the engagement was to the inventor a disaster'.[71]

Glum reflection was balanced by enthusiastic exhibition. During 1876, when the calculating engine was on show and occasionally working at the South Kensington exhibition of scientific apparatus, Henry lent his father's examples of much older calculating devices such as those of Samuel Morland (1660s) and Charles Stanhope (1770s) to be juxtaposed with his father's machine. The following year, the distinguished railway engineer William Prime Marshall lectured on the history of Babbage's machine at the Birmingham Philosophical Society, describing the engine as a 'mechanical treat' at last put on proper public display.[72] A similar performance took place at the Manchester Society of Chartered Accountants when its president, the statistician and Liberal politician Edwin Guthrie, evoked the South Kensington display of calculating devices during a lecture on the history of numeration. Guthrie's Manchester lecture was accompanied by an exhibition of model calculating machines, including Thomas de Colmar's arithmometer, slowly becoming standard if not always reliable issue in the major insurance firms, and, once again, Babbage's example of Stanhope's calculating machine 'which had never been in the provinces before'. Importantly, Henry also lent the Manchester accountants 'a small original portion of a machine' designed 'to exhibit the principle of the Difference Engine'.[73] This reference is suggestive, since as the example of the Whipple engine shows, there were indeed several fragmentary models of the mechanism of the difference engine assembled in 1878–9 and in circulation during the 1880s through Henry Babbage's enterprise. Significantly for the politics of memory and

Noise and Artificial Intelligence: Babbage's London', in J. Q. Davies and E. Lockhart (eds.), *Sound Knowledge: Music and Science in London 1789–1851* (Chicago: University of Chicago Press, 2016), pp. 203–25, on pp. 203–4.

71 H. Babbage, 'Paper Read at Bath, 12 September 1888', in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), pp. 331–7, on p. 337; and [H. Babbage], 'Calculating Machines' (1888), *Chambers's Encyclopaedia*, new edn (Edinburgh: Chambers, 1901), pp. 633–4. Henry's proof copy of the *Chambers* entry is at Powerhouse Sydney, Museum of Applied Arts and Sciences MS 97/186/1-5/1/31, p. 14.

72 *Catalogue of the Special Loan Exhibition*, pp. 5–6; and W. P. Marshall, 'Babbage's Calculating Machine', *Proceedings of the Birmingham Philosophical Society*, 1 (1879), pp. 33–48, on p. 45.

73 E. Guthrie, 'The Development of the Art of Numeration', *The Accountant*, 10, no. 518 (8 November 1884), pp. 7–15, on pp. 12, 14. The arithmometer's career is described in Johnston, 'Making the Arithmometer Count'.

display, they were part of his active campaign to exhibit and recall the historic principles on which his father's engine had worked.

During 1878–9, Henry at last recalled the project he and Charles had briefly tried back in 1855, the construction of a working fragment of the carriage and addition mechanisms of the difference engine. Once again, his memory of the details was inconsistent. Emulating the managers of saintly relics, Henry decided to make a whole series of such small models, eventually presenting some as gifts, though the exact number is not clear. In a manuscript note of December 1884 he referred to 'six specimen pieces'. In a similar document of December 1886 he mentioned 'seven fragments'. In a printed editorial of October 1888 he listed six 'sample pieces', and in his 1910 *Memoirs* he counted 'five small separate pieces'.[74] Apart from the Whipple Museum fragment, only three others assembled by Henry are extant. One was despatched to Harvard, a destination that might have recalled the Harvard physician Bowditch's visionary plans for a 'work of art' half a century earlier. The Harvard device was sent in December 1886 at the same time as that for Cambridge University. Henry also presented a piece to University College London, his alma mater and erstwhile base for Lardner and Watkins, a model transferred to the Science Museum in 1967 (Figure 6.6). A similar sample acquired by Henry's nephew and Benjamin's son Charles Whitmore Babbage, surveyor, clerk, convicted fraudster, and farmer in South Australia and New Zealand, has since 1996 been held by the Powerhouse Museum in Sydney. In 1888 Henry also mentioned a gift to Owens College Manchester, though it is possible that there was some confusion with the model shown at Guthrie's October 1884 lecture in the city or perhaps through some connection with the College's great patron Whitworth, who died in 1887. In any event, no model of the difference engine survives anywhere in Manchester.[75]

74 H. Babbage, 'Note on Specimen Piece of Babbage's Difference Engine' (December 1884), in Tee, 'The Heritage of Charles Babbage in Australasia', p. 59; H. Babbage, 'History of This Fragment' (December 1886), in Cohen, 'Babbage and Aiken', p. 185; H. Babbage, 'Conclusion' (October 1888), in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), p. 341; and H. Babbage, *Memoirs and Correspondence*, p. 225.

75 Inventory numbers of extant machine fragments are Harvard Collection of Historical Scientific Instruments 1991-1-0001a; Science Museum London 1967–70; and Sydney Museum of Applied Arts and Sciences 96/203/1. For Bowditch see Williams, 'Babbage and Bowditch', p. 285; for Charles Whitmore Babbage see S. O. Reader, *The Vision Splendid* (Canberra: National Library of Australia, 2011), pp. 116–21; and Tee, 'The Heritage of Charles Babbage in Australasia', pp. 51–53. Thanks are due to James Sumner and Erin Beeston for help with Manchester sources.

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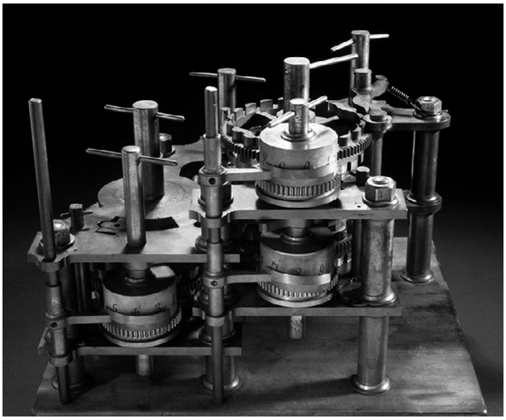

Figure 6.6 Henry Babbage's model of the difference engine mechanism with three cages assembled in 1879 and presented to University College London. By permission of the Science and Society Picture Library (Science Museum 1967–70).

Like the Whipple piece, the fragments at Harvard and in Sydney are also accompanied by Henry's instructions, which vary but little among themselves, though, in contrast to the Cambridge notes' indication of the novelty of some of the components, the notes for Harvard mention that 'the whole is dull with time and dust' and that the lever might not sit on the teeth of the crown wheel 'from dirt and weakness of the spring', while the Sydney notes uniquely refer to the whole engine's calculating mechanism as composed of no fewer than eighteen figures in the result column. Henry's *Memoirs* are also somewhat confused about the details of the models he made and sent as gifts. He misremembered that the Harvard model, and the fragment for his own use, were 'of five cages each, to show two figures added to three', while all the others showed the addition of one figure to two figures. Yet in fact, like those in London and Sydney, the Harvard model carries only three cages; the sole extant model with as many as five cages is that in the Whipple Museum.[76]

Just before despatching model fragments of the machine to British and North American universities, the sixty-year-old Henry and his family moved away from Bromley to Cheltenham in 1885. He took with him the materials for a small workshop, including the lathe originally acquired from Clement.[77] He never again did any work on the difference

76 Cohen, 'Babbage and Aiken', p. 185; Tee, 'The Heritage of Charles Babbage in Australasia', p. 59. There are also early difference engine fragments at the Museum of the History of Science, Oxford, no. 94229, which were given by Charles Babbage to Harry Buxton; and at the Macleay Museum, University of Sydney, object no. 1993.3, components presented by Nevil Francis Babbage, great-grandson of Benjamin. Thanks are due to Jude Philp at the Macleay Museum for her help.

77 H. Babbage, *Memoirs and Correspondence*, pp. vi–vii, 228. The Clement lathe is presumably Science Museum London object no. 1878–89.

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engine. The models he sent out in 1886 were thus a form of terminal valediction. From then on, it was the mill of the analytical engine that absorbed attention. In September 1888 he travelled from Cheltenham to Bath to lecture the British Association on the analytical engine, and the following month added he the text of this lecture to a large printed collection put together when in Bromley, consisting of papers by his father and other protagonists of the engineering project designed to offer a synoptic history of the calculating engines. He told his readers that it was because of his father's dying bequest of the 'calculating machines and all that belonged to them at my absolute disposal . . . and not to any special fitness for the task that it has fallen to me to complete it'. In several respects, notably its stress on the power of recall and surveillance offered by the system of mechanical notation, and the elegance of memory and anticipation embodied in the analytical mill, the 1888 lecture and publication were to be read as a long riposte to Merrifield's pessimistic BAAS report of a decade earlier, though Henry conceded finally that he saw 'no hope of bringing any profit to its constructor'.[78]

Nevertheless, he did renew his enterprise to build the mill. During 1888 he once again contacted Munro at Tottenham, whose firm worked with Henry's advice to complete a cast iron bed for the mill together with the rudiments of the steel cam mechanisms for number carriage. Visitors such as the ingenious South Kensington physics lecturer Charles Vernon Boys, who designed his own machine to effect carriage and was an authority on office calculating machines and arithmometers, visited Cheltenham to see the mill and learn how simultaneous carriage, with its elegant principle of anticipation, was achieved. The mill project lasted eight years, at the end of which Henry was discouraged by systematic errors in the smooth running of the machine when calculating multiples of π, halted the work and deposited the mill in the South Kensington Museum (Figure 6.7).[79] At the same time, in 1896, the elderly retired Indian general travelled up from Cheltenham to the offices of the best-selling *Strand Magazine* in London, a journal then otherwise best

78 H. Babbage, 'Preface' and 'Paper Read at Bath, 12 September 1888', in H. Babbage (ed.), *Babbage's Calculating Engines* (London: Spon, 1889), pp. 331–7, on p. 337.

79 H. Babbage, *Memoirs and Correspondence*, p. 227; H. Babbage, 'Babbage's Analytical Engine', pp. 518–19; and Charles Boys in 'Meeting of the Royal Astronomical Society, 8 April 1910', *The Observatory*, 33 (1910), pp. 191–201, on pp. 195–6. Thanks are due to Joshua Nall for this reference. For Boys and arithmometers, see A. Warwick, 'The Laboratory of Theory', in M. Norton Wise (ed.), *The Values of Precision* (Princeton: Princeton University Press, 1995), pp. 311–51, on p. 334.

Figure 6.7 The analytical engine mill completed by R. W. Munro for Henry Babbage in 1906–10. By permission of the Science and Society Picture Library (Science Museum London 1896–0058).

known for its publication of Conan Doyle's detective stories, to advise the journalist William Fitzgerald on appropriate coverage of the display of the difference engine model and the analytical mill at the Museum.[80] From 1906, Henry would pay further regular visits to the Museum to inspect the model, devise more alterations, notably to the anticipating carriage, and devise a new printing mechanism. 'He was not a mathematician', so the Science Museum's mathematics curator David Baxandall remembered, but Henry 'looked upon it as a duty to try and complete some little portion of the analytical engine which his father had designed but only partially constructed'. The same year Henry decided to resuscitate his work with Munro's workshop, which eventually organised the analytical printer to generate impressions of a sequence of multiples of π to twenty-eight places.[81]

In 1910–11 Henry staged his last set of exhibitions of the calculating engines. In April 1910 he took the printouts from the mill to a meeting of the Royal Astronomical Society at Burlington House, where he gave a talk to the astronomers on the analytical engine and showed a photograph of the device: he lauded the aim to use mechanical calculators to unveil 'the laws of the Cosmos', referred to the sacred trust granted by his father's legacy, and explained that he had 'endeavoured to complete the work as far as the instructions in

80 W. Fitzgerald, 'The Romance of the Museums, Part 5', *Strand Magazine*, 11 (January 1896), pp. 710–15, on p. 713.

81 D. Buxton, 'Charles Babbage and His Difference Engine', *Transactions of the Newcomen Society*, 14 (1933), pp. 43–65, on p. 60.

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the hands of the workmen permitted'. Charles Boys was at the meeting to express his continuing puzzlement about the analytical mill's mechanisms for recall and anticipation. The Cambridge astronomy professor Robert Ball reminisced, if 'a treacherous memory is not deceiving me', that as late as 1865 Charles Babbage had 'young men specially trained as highly skilled mechanics for the purpose of remarking on the construction of the analytical engine'. Embarrassingly, in the 1910 display mistakes in the value of π fed into the machine, and weakness in the printer's springs led to errors in the output.[82]

Undeterred by this publicity setback, Henry then arranged for the mill to be put on show both at the Astronomical Society's soirée and more publicly at the prodigious entrepreneur Imre Kiralfy's glamorous and crowded exhibitions at White City, the British–Japanese exhibition of 1910 and the Coronation exhibition of 1911. The mill and printer were placed in the British Science section near Lyons restaurant and the Wood Lane underground station: Henry grumbled that there was 'no one to explain it on these occasions and no great interest was taken in it. After this it went back to the Museum.'[83] By summer 1914, on the eve of war, the devices appeared in Edinburgh in a display of calculating machines marking the tercentenary of Napier's invention of logarithms, but merely as a Science Museum photograph alongside other images of the difference engine and a commemorative portrait of Charles Babbage himself.[84] In his notes for the display, the Dublin accountant Percy Ludgate summed up the achievements of the Babbage enterprise, before then announcing his own development of a completely newfangled analytical engine. The Babbage machines were now consigned to a past of original invention, with a singular and heroic inventor and tragic aftermath.[85]

82 H. Babbage, 'Babbage's Analytical Engine', p. 518; H. Babbage, 'Meeting of the Royal Astronomical Society', pp. 195–7; and H. Babbage, 'Errata', *Monthly Notices of the Royal Astronomical Society*, 70 (June 1910), p. 645.

83 H. Babbage, *Memoirs and Correspondence*, p. 228; and *Coronation Exhibition Official Guide and Catalogue* (Derby: Bemrose, 1911), p. 120. See Swade, *The Cogwheel Brain*, p. 315.

84 E. M. Horsbugh (ed.), *Modern Instruments and Methods of Calculation* (London: Bell, 1914), p. 27.

85 P. Ludgate, 'Automatic Calculating Machines', in E. M. Horsbugh (ed.), *Modern Instruments and Methods of Calculation* (London: Bell, 1914), pp. 124–7 describes the Babbage machines; for his own engine see B. Randell, 'Ludgate's Analytical Machine of 1909', *Computer Journal*, 14 (1971), pp. 317–26.

The fragment of the model difference engine on display in the Whipple Museum had a much humbler fate than the analytical mill in South Kensington: Wilkes had told Bryden that to call the Whipple model 'epoch making' was to confuse it with the analytical engine.[86] The relationship between such projects and their makers' repute has become even more marked since the assemblage of a working version of the second of Babbage's difference engine schemes at the Science Museum in 1985–91, launched in an exhibition called *Making the Difference* alongside corresponding hagiographies both of machine and of individual author: 'Museum revives Georgian genius's technology'.[87] All these devices share significant patriarchal, technical, and economic histories, different versions of a plan for a world-machine managed by what Farr once called a 'political Newton'. Babbage's difference engine was proposed and funded as a device for the manufacture of printed tables, and its function showed the close if perhaps surprising relationship between calculation and measurement. The disciplinary organisation of precision measures in the workshop was very closely related to the reliability of the calculation of successive terms in a mathematical series. While the former seemed to be a matter of judgment and skill in gearcutting and forging, proper to the engineering workshop, the latter was surely merely a question of following a rule, appropriate for the student's study and the actuary's desktop. The fate of the Babbage engines showed this contrast was illusory: to organise computation was always also to organise labour. At successive public exhibitions in South Kensington, Manchester, and White City, the calculating engines were displayed alongside impressive tables and humbler desktop calculators. The arithmometers that, unlike the difference engine, did come to dominate government and private calculation offices could become sites of skill and conflict; and by 1910 were not used to make tables but to replace them by performing computation directly. Displays of the model difference engines should juxtapose and connect them with these modest and indispensable contemporaries, rather than persistently seeking to find the ancestry of the modern electronic computer somewhere buried inside Henry Babbage's device.[88]

86 Wilkes to Bryden, 4 March 1977, Whipple Museum archive P 011.

87 Purbrick, 'The Dream Machine', pp. 15–19; and Swade, *The Cogwheel Brain*, p. 279.

88 Warwick, 'The Laboratory of Theory', pp. 331–6; Johnston, 'Making the Arithmometer Count'; and Schivelbusch, 'World Machines', pp. 59–61.

That device is a relic, an object deliberately designed to evoke certain souvenirs of filial piety alongside the ingenious manipulation of storage and recall. When Charles and Henry Babbage assembled their very first version of the five-cage difference engine model in 1855, London was agog with the display of the relics of the Franklin expedition to the Arctic and its evidently tragic fate. Dismembered equipment, machinery, and more mundane materials from Babbage's friend John Franklin's catastrophic voyage to the Beaufort Sea were put on show just round the corner from Dorset Street at the Polytechnic Institution. In this presentation of melancholy polar detritus at the Institution where 'scientific discoveries thrown off hot from the brain' were normally displayed, components of a technically sophisticated mid-Victorian steam-driven scientific and political enterprise became a means, through an exhibition, of imagining the salvage of a project that was nevertheless decisively lost. The project became intensely identified with the persona of the solitary hero, martyred by an unforgiving establishment. The analogy with the calculating engine enterprise is instructive – an assemblage for public display of a set of relics of an endeavour that might, at least in the imagination, somehow be rescued from oblivion. The souvenir and the machine played crucial roles in this relic cult and its complex motivations.[89] Babbage himself had a model of how such memories and relics might survive forever, through the traces left in the atmosphere. It might be apt to accompany the museum display of the difference engine model with a recording of the noisy warning it issues during carriage – listeners might then just catch the traces of all the memorable histories embodied in its workings.

89 Craciun, *Writing Arctic Disaster*, pp. 45–50.

Appendix

Henry Babbage's notes on the model fragment of the difference engine sent to Cambridge in December 1886: Whipple Museum MS 2339

[Sheet 1: Contents]

Contents of this box

A piece of 5 figures. Diff. Engine

5 German silver rings with numbers 0 to 9 engraved. These have to be mounted.

4 screens. These require a little fitting, and a mark made on each for the index guide (see print). They also want screws to keep them in position when raised to hide the figure.

A pamphlet prepared for S. Kensington but useful here.

H P Babbage

Dec 1886

—

[Sheet 2: Instructions]

To work the Machine

The Axes have the numbers I, II and III attached to them.

The axis No. II should be so placed that the sliding bolts fixed to it are perpendicular to the front or face of the Machine. In this fragment this must be adjusted by hand: this having been done

Axis No. I must be turned once which will shoot the sliding bolts in all cases except where the figure is 0.

Axis No. II should then be turned a half circle:- this will do addition, the figure on the left hand column being added to that on the right hand one, the first remaining, the second of course changing and if a 'carriage' has become necessary the warning lever will have moved (giving a 'click')

Axis No. III should now be turned and the 'carriage' will be made and the calculation completed.

Where any difference is *minus* the complement is added.

H P Babbage

Dec 1886.

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[Sheet 3: Note]

Note

The german silver rings with the numerals engraved on them have been made recently and never fitted on. The figures run reverse ways on the adjacent columns. Five are sent. In fitting them on care should be taken that the Index of the figure wheel is about mid way between 0 and 9 when the carriage warning lever is released.

The index is on the screen in front: four screens are sent and require slight fitting. On each of them should be made a mark thus ◆ (see print) which is the Index or guide to the figure and when the figure is not wanted in the calculation or for any reason it is wished to hide it, the screen can be raised and so brought over the figure. The print in the S. K. pamphlet will be found useful in making these arrangements.

H P Babbage