Introduction

CHARLES BABBAGE is known today as the great pioneer of computing. As computers spread through commerce and industry, banking and insurance, national and local government, science and mathematics, school and university education, and through society all round the world, so Babbage has joined his countrymen Faraday, Newton, and Darwin in the pantheon of popularly celebrated men of science.

The ubiquitous application of modern computing makes it singularly fitting that Babbage's own interests were also remarkably wide. Starting as a mathematician he turned to calculating and printing numerical tables: the manufacture of number. The study of mechanical devices for use in his Calculating Engines led Babbage on to an extraordinarily thorough and wide-ranging study of British industry. He generalized this study to include political economy, and his book *On the Economy of Machinery and Manufactures* was an important influence on nineteenth-century political economists, particularly John Stuart Mill and Karl Marx.

In May 1812, while he was at Cambridge, Babbage and some friends founded the Analytical Society to discuss mathematics and encourage introduction of the Leibniz 'd' notation for the calculus to replace Newton's 'dot' notation. It was not only that the Leibniz notation was the more powerful of the two: after the death of Newton mathematics had advanced far more rapidly on the continent, while British mathematicians, often unable even to read foreign mathematics because the notation used was unfamiliar, lagged far behind. The Young Turks of the Analytical Society were successful in their campaign for the Leibniz 'd's, and the Cambridge Philosophical Society was the posthumous offspring of the Analytical Society. However, Babbage and his friends had far more ambitious objectives in view: they sought to develop science throughout Britain and use it to change society. In this grand scheme Charles Babbage was the leading figure.

The liberals of the time were profoundly influenced by the French Revolution. Lazare Carnot, 'Organizer of Victory', and his associates had established the Grandes Ecoles with their emphasis on science, and under French influence technical high schools and other institutions for scientific training were established in continental Europe. Moreover Napoleon fostered science with an eye to its military use. Babbage and his friends sought to learn from France and develop national support for scientific institutions, and particularly for scientific and technical education and training in Britain. The movement came to its climax in the Decline of Science campaign, the scientific counterpart of the political movement for the Great Reform Bill.

Babbage wrote a highly polemical book *Reflections on the Decline of Science in England, and on Some of its Causes*, which sought to reform the Royal Society, scientific education in England, and much else besides. The movement centred on the campaign to elect John Herschel, rather than a royal duke, as president of the Royal Society. Herschel was defeated and the Royal Society did not become a professional body until later in the century. Babbage's proposals for scientific and technical education were entirely ignored[1]; so also were his plans for the systematic application of scientific method to British commerce and industry.

Recently, with the growing realization of the deep-seated nature of Britain's industrial problems and the attempt to restructure British industry on a scientific basis making extensive use of computing, there has been renewed interest in the earlier stages of Britain's industrial development. In the *Audit of War* (Macmillan, 1986) Correlli Barnet not only showed the disastrous state of British industry during the second world war, but traced Britain's industrial problems to the second half of the nineteenth century. However, it is clear that the roots of these problems reach much deeper into history: they are structural weaknesses which developed as the country built the world's first industrial economy. Britain's industry was created by practical men with scarcely any direct assistance from the higher reaches of science, but by the 1820s it was becoming clear that industry could not continue to develop satisfactorily without scientific method. Babbage and his friends fought the battle for the systematic development and application of science on a national level, and lost. The consequences of this defeat are the subject of the current debate.

During the 1830s a profound split opened between pure science, which became the province of the universities, and the mundane bread and butter technical and engineering problems of industry. The Royal Society was ineffectual for decades and the professional civil service was established almost entirely without scientific input. To this day the bulk of the British civil service, particularly in the senior grades, is scientifically illiterate, and the consequences, from defence procurement[2] to education planning and scientific research, have been disastrous. Britain's weakness in the new science-based industries which developed towards the end of the nineteenth century has been endemic since their inception. As the sons of the men who had created Britain's staple industries were educated at public schools, moving into the City and becoming country gentlemen, so the standard of management in industry declined.

The government had backed Babbage's first Difference Engine, which was designed to calculate tables according to the method of finite differences and then to print the tables. After 1833 government support ceased, though it was another decade before the project was formally abandoned, and the government's treatment of Babbage led Dickens to create the celebrated Circumlocution Office of *Little Dorrit*.

In 1834 Babbage turned his attention to designing calculating machinery for more general mathematical operations, and started on the work which led to his great series of Analytical Engines. Although Babbage's impact on industrial development was of great importance in the British context, for the world at large Babbage is thought of as the founder of computing. The Analytical Engines incorporated an extraordinary range of concepts which were to reappear in modern computing. Separate store and mill; binary-coded store-addressing, and fast carry mechanism; versatile input/output system with a range of output devices; program control; microprogram control of the small operations – all belong to the first half of the nineteenth century. Array processing followed in the 1860s.

During his main period of work on the Analytical Engines, from 1834 to 1847, Babbage was making feasibility studies and preparing plans. It is often asked whether an Analytical Engine would actually have worked if one had been built. Thus phrased the question is not obviously meaningful. Many things can go wrong during a project of such complexity, and Babbage would certainly have made many alterations and developments during construction. However the question can be put somewhat differently: would it have been feasible for Babbage and Whitworth to have constructed a working Analytical Engine during the 1850s? When I came to make a detailed study of the Analytical Engines about fifteen years ago I formed the opinion that there was no technical reason why an Analytical Engine should not have been constructed.[3] The problem was financial. For an Analytical Engine to have been made in the nineteenth century, Babbage would have required a private fortune like that of Henry Cavendish in the eighteenth century: public finance was out of the question. It might have been necessary to go round the loop twice, with a development model and a working engine, but technically the project in itself was perfectly feasible.

Two of the main works represented here, 'Babbage's Calculating Engines' (1834), and 'Sketch of the Analytical Engine' (1843), were written by others under Babbage's careful direction. They were the first extensive descriptions published of the uses of the Difference and Analytical Engines, respectively.

Notes

1 C.f. Prof. Margaret Gowing, Wilkins Lecture, *Notes and Records*, 32 (1), July 1977.

2 A recent example of the damage caused by having scientifically incompetent senior civil servants is waste disposal. Britain, with far laxer laws than its neighbours, is in danger of becoming the rubbish tip of North Europe. No doubt the Department of the Environment has its scientific advisers, but that is rarely sufficient when the top people are quite incapable of grasping the technical essence of the underlying issues.

A longer-term example is radar, where Britain appears to have been virtually without radar-controlled defences since the wartime systems became obsolete. This has been common gossip in the industry for decades, but the full horror of the situation was only brought out recently in Duncan Campbell's television series *The Secret State*. All the military espionage since the war must pale into triviality when compared with the damage caused by the technical incompetence of the defence procurement agencies, incompetence, it may be remarked, of which secrecy is itself a principal cause.

3 In a letter to *The Times* published on 20 December 1982 I proposed the construction of an Analytical Engine:

> The Manpower Services Commission has recently sponsored construction of a replica of Stephenson's Rocket. I should like to suggest that it would be appropriate, in Information Technology Year, to consider construction of working versions of Charles Babbage's calculating engines. It might be sensible to start with the second Difference Engine and then one of the more simple plans for Analytical Engines.
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> This project would provide unique training in a combination of mechanical engineering and digital techniques. It would also make a fitting tribute to the Englishman who pioneered computing in the middle of the nineteenth century.

Manufacture of a complete first Difference Engine presents some problems as most of the drawings have been lost. After the government project to make the first Difference Engine had ended, the small completed portion was transferred to the museum at King's College in the Strand. This portion was shown at the Exhibition of 1862 and then removed to the Science Museum in South Kensington, as the authorities at King's College declined to receive it again. When the accompanying drawings were transferred to the Science Museum in recent years most were missing. Thus King's College has distinguished itself not only by rejecting the first Difference Engine but by losing the bulk of the historic drawings into the bargain.

One might add that as museums all around the world develop sections on the history of computing, and thus come to seek working models of Babbage's Engines, the construction of Difference and Analytical Engines might form the basis of a nice export trade, a consummation of which Babbage would have entirely approved.

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Anthony Hyman
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Family background and education

CHARLES BABBAGE came from old Devonshire stock and both his parents belonged to leading Totnes families. Bab, or Babb, is a very old Devon name, but Babbage and similar forms do not seem to appear before the end of the sixteenth century, while families were still changing their names from Bab to Babbage in the nineteenth. There was a family tradition that an ancestor of Babbage had been left behind in France after the fall of Calais, and that four brothers, his sons, had returned to Devon during the reign of Elizabeth. Babbage's forebears appear in Totnes rate books early in the seventeenth century under the name of Babbidge. Presumably the French could not wrap their tongues round the gutteral Bab, and the family had become *la famille Babbidge*.

In *Passages from the Life of a Philosopher*, p. 6, Babbage refers to a curious story involving a relative of his, one Richard Babbage who became involved with Bamfylde Moore Carew, the King of the Beggars. Richard's escapades led to complications about some property at Ashbrenton, a name which has caused some confusion. 'Ashbrenton' was actually an alternative old name for Ashprington near Totnes.

Babbage's paternal family were goldsmiths but his father, Benjamin, had become a banker and moved to London, where Charles was born on 26 December 1791. The family returned to Devonshire when Benjamin retired in about 1803. After a fragmentary schooling Charles Babbage entered Trinity College, Cambridge in 1810, migrating to Peterhouse in 1812.

Passages from the Life of a Philosopher, p. 34

Whilst I was an undergraduate, I lived probably in a greater variety of sets than any of my young companions. But my chief and choicest consisted of some ten or a dozen friends who usually breakfasted with me every Sunday after chapel; arriving at about nine, and remaining to between twelve and one o'clock. We discussed all knowable and many unknowable things.

Passages from the Life of a Philosopher, pp. 35–8

During the first part of my residence at Cambridge, I played at chess very frequently, often with D'Arblay and with several other good players. There was at that period a fellow-commoner at Trinity named Brande, who devoted almost his whole time to the study of chess. I was invited to meet him one evening at the rooms of a common friend for the purpose of trying our strength.

On arriving at my friend's rooms, I found a note informing me that he had gone to Newmarket, and had left coffee and the chessmen for us. I was myself tormented by great shyness, and my yet unseen adversary was, I understood, equally diffident. I was sitting before the chess-board when Brande entered. I rose, he advanced, sat down, and took a white and a black pawn from the board, which he held, one in either hand. I pointed with my finger to the left hand and won the move.

The game then commenced; it was rather a long one, and I won it: but not a word was exchanged until the end: when Brande uttered the first word. 'Another?' To this I nodded assent.

How that game was decided I do not now remember; but the first sentence pronounced by either of us, was a remark by Brande, that he had lost the first game by a certain move of his white bishop. To this I replied, that I thought he was mistaken, and that the real cause of his losing the game arose from the use I had made of my knight two moves previously to his white bishop's move.

We then immediately began to replace the men on the board in the positions they occupied at that particular point of the game when the white bishop's move was made. Each took up any piece indiscriminately, and placed it without hesitation on the exact square on which it had stood. It then became apparent that the effective move to which I had referred was that of my knight.

Brande, during his residence at Cambridge, studied chess regularly several hours each day, and read almost every treatise on the subject. After he left college he travelled abroad, took lessons from every celebrated teacher, and played with all the most eminent players on the Continent.

At intervals of three of four years I occasionally met him in London. After the usual greeting he always proposed that we should play a game of chess.

I found on these occasions, that if I played any of the ordinary openings, such as are found in the books, I was sure to be beaten. The only way in which I had a chance of winning, was by making early in the game a move so bad that it had not been mentioned in any treatise. Brande possessed, and had read, almost every book upon the subject.

Another set which I frequently joined were addicted to sixpenny whist. It consisted of Higman, afterwards Tutor of Trinity; Follet, afterwards Attorney-General; of a learned and accomplished Dean still living, and I have no doubt still playing an excellent rubber, and myself. We not unfrequently sat from chapel-time in the evening until the sound of the morning chapel bell again called us to our religious duties.

I mixed occasionally with a different set of whist players at Jesus College. They played high: guinea points, and five guineas on the rubber. I was always a most welcome visitor, not from my skill at the game; but because I never played more than shilling points and five shillings on the rubber. Consequently my partner had what they considered an advantage: namely, that of playing guinea points with one of our adversaries and pound points with the other.

Totally different in character was another set in which I mixed. I was very fond of boating, not of the manual labour of rowing, but the more intellectual art of sailing. I kept a beautiful light, London-built boat, and occasionally took long voyages down the river, beyond Ely into the fens. To accomplish these trips, it was necessary to have two or three strong fellows to row when the wind failed or was contrary. These were useful friends upon my aquatic expeditions, but not being of exactly the same calibre as my friends of the Ghost Club, were very cruelly and disrespectfully called by them 'my Tom fools.'

The plan of our voyage was thus:—I sent my servant to the apothecary for a thing called an aegrotat, which I understood, for I never saw one, meant a certificate that I was indisposed, and that it would be injurious to my health to attend chapel, or hall, or lectures. This was forwarded to the college authorities.

I also directed my servant to order the cook to send me a large well-seasoned meat pie, a couple of fowls, &c. These were packed in a hamper with three or four bottles of wine and one of noyeau. We sailed when the wind was fair, and rowed when there was none. Whittlesea Mere was a very favourite resort for sailing, fishing, and shooting. Sometimes we reached Lynn. After various adventures and five or six days of hard exercise in the open air, we returned with our health more renovated than if the best physician had prescribed for us.

During my residence at Cambridge, Smithson Tennant was the Professor of Chemistry, and I attended his lectures. Having a spare room, I turned it into a kind of laboratory, in which Herschel worked with me, until he set up a rival one of his own. We both occasionally assisted the Professor in preparing his experiments. The science of chemistry had not then assumed the vast development it has now attained. I gave up its practical pursuit soon after I resided in London, but I have never regretted the time I bestowed upon it at the commencement of my career.

When he went up to Cambridge Babbage was equally familiar with the three notations then commonly in use for the calculus: Newton's dots, Lagrange's dashes, and, by far the most powerful, the Leibniz 'd's. Passing through London on his journey from Devon, Babbage had purchased Lacroix's *Differential and Integral Calculus*, which used the Leibniz notation, for the huge price of seven guineas. No sooner was he installed in his rooms than Babbage buried himself in his new purchase. Hopefully Babbage asked his tutors to explain some difficulties, but discovered to his dismay that they were quite incapable of understanding the problems.

Passages from the Life of a Philosopher, pp. 27–9

I thus acquired a distaste for the routine of the studies of the place, and devoured the papers of Euler and other mathematicians, scattered through innumerable volumes of the academies of Petersburgh, Berlin, and Paris, which the libraries I had recourse to contained.

Under these circumstances it was not surprising that I should perceive and be penetrated with the superior power of the notation of Leibnitz.

At an early period, probably at the commencement of the second year of my residence at Cambridge, a friend of mine, Michael Slegg, of Trinity, was taking wine with me, discussing mathematical subjects, to which he also was enthusiastically attached. Hearing the chapel bell ring, he took leave of me, promising to return for a cup of coffee.

At this period Cambridge was agitated by a fierce controversy. Societies had been formed for printing and circulating the Bible. One party proposed to circulate it with notes, in order to make it intelligible; whilst the other scornfully rejected all explanations of the word of God as profane attempts to mend that which was perfect.

The walls of the town were placarded with broadsides, and posters were sent from house to house. One of the latter form of advertisement was lying upon my table when Slegg left me. Taking up the paper, and looking through it, I thought it, from its exaggerated tone, a good subject for a parody.

I then drew up the sketch of a society to be instituted for translating the

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small work of Lacroix on the Differential and Integral Calculus. It proposed that we should have periodical meetings for the propagation of d's; and consigned to perdition all who supported the heresy of dots. It maintained that the work of Lacroix was so perfect that any comment was unnecessary.

On Slegg's return from chapel I put the parody into his hands. My friend enjoyed the joke heartily, and at parting asked my permission to show the parody to a mathematical friend of his, Mr. Bromhead.

The next day Slegg called on me, and said that he had put the joke into the hand of his friend, who, after laughing heartily, remarked that it was too good a joke to be lost, and proposed seriously that we should form a society for the cultivation of mathematics.

The next day Bromhead called on me. We talked the subject over, and agreed to hold a meeting at his lodgings for the purpose of forming a society for the promotion of analysis.

At that meeting, besides the projectors, there were present Herschel, Peacock, D'Arblay, Ryan, Robinson, Frederick Maule, and several others. We constituted ourselves 'The Analytical Society;' hired a meeting-room, open daily; held meetings, read papers, and discussed them. Of course we were much ridiculed by the Dons; and, not being put down, it was darkly hinted that we were young infidels, and that no good would come of us.

In the meantime we quietly pursued our course, and at last resolved to publish a volume of our Transactions. Owing to the illness of one of the number, and to various other circumstances, the volume which was published was entirely contributed by Herschel and myself.

At last our work was printed, and it became necessary to decide upon a title. Recalling the slight imputation which had been made upon our faith, I suggested that the most appropriate title would be—

The Principles of pure D-ism in opposition to the Dot-age of the University.