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Abstract A greatly expanded treatment is presented of the history of the family, life and work of Percy Ludgate, nearly fifty years after the 1971 and 1982 papers by Randell revealed his work on a mechanical computer, and almost 100 years after Ludgate's death. The new material that has recently been obtained about this successor of Charles Babbage includes two very significant discoveries. The first is of a hitherto unknown contemporary published description of Ludgate's Analytical Machine, incorporating the only surviving drawing of it yet found; the second is of American descendants of Ludgate's niece, who have been allowed to erect a commemorative headstone on his previously unmarked grave.

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I. INTRODUCTION

The story of how in 1834, over a hundred years before the first electronic computers, the brilliant but eccentric English scientist, Charles Babbage, started to design a huge sequence-controlled mechanical digital computer,¹ his 'Analytical Engine',² to improve on the human 'computers' then employed,³ is reasonably well-known. However, less is known of Percy Edwin Ludgate, who was the second person to design a sequence-controlled mechanical digital computer in the pre-electronic era.

Remarkably, Ludgate, who was born in Skibbereen in 1883 and employed in Dublin until his death in 1922, was just a clerk to a corn merchant and subsequently a qualified accountant. He worked on his design in his spare time between 1903 and 1909, and was not aware of Babbage's work until his initial design was completed. His 'Analytical Machine',⁴ as he called it, was quite unlike Babbage's in that it was largely based on multiplication using novel mechanical ideas, while Babbage's was very different mechanically,

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¹ A 'sequence-controlled digital computer' is known as a 'program-controlled digital computer' or 'programmable digital computer', typically abbreviated to 'digital computer' in modern terminology.

² Ada Lovelace, 'Sketch of the analytical engine invented by Charles Babbage, esq. by L.F. Menabrea, of Turin, officer of the military engineers, with notes by the translator', in Richard Taylor (ed.), *Scientific Memoirs* (London, 1843), vol. 3, 666-731. Available at: <https://www.scss.tcd.ie/SCSSTreasuresCatalog/literature/TCD-SCSS-V.20121208.870/TCD-SCSS-V.20121208.870.pdf>

³ A term used since the early seventeenth century for a person performing mathematical calculations.

and was, more conventionally, based on addition. Randell's 1982 paper states that 'although Ludgate had, at least during the later stages of his work, known of Babbage's machine, much of his work was clearly entirely original – and indeed with respect to program control, a distinct advance on Babbage's ideas. In fact, all three main components of Ludgate's Analytical Machine – the store, the arithmetic unit, and the sequencing mechanism – show evidence of considerable ingenuity and originality'.⁵

Both machines embraced the core concept of being able to be automatically sequenced through a set of operations,⁶ using perforated paper in Ludgate's case, Jacquard-style strung-together punched cards in Babbage's, and in particular both machines supported what is now known to be the critical concept of being able to change the sequencing mechanism's behaviour based on the results of prior calculations.⁷ Thus both machines would be capable of doing everything a modern computer of their scale and class could do, although very slowly. If they had not incorporated these concepts, both the designs and their designers would be much less significant with respect to the history of computing.

Ludgate died in 1922, his work already having faded into obscurity. Almost nothing further was heard of him until Randell's 1971 and 1982 papers,⁸ and Riches' 1973 project.⁹ Since then Ludgate's work has often been described in general accounts of the history of computing, and there have been many summaries of Randell's papers, in, for example, the *Dictionary of Irish Biography*,¹⁰ although nothing new was published until Jim Byrne's 2011 paper provided some extra detail on Ludgate's parents.¹¹ Meanwhile, in 1991, the Department of Computer Science in Trinity College Dublin instigated an annual prize in his memory,¹² the only official recognition worldwide until recently.

⁴ Percy E. Ludgate, 'On a proposed analytical machine', *Scientific Proceedings of the Royal Dublin Society* 12:9 (Dublin, 28 Apr. 1909), 77-91. Available at: <https://www.scss.tcd.ie/SCSSTreasuresCatalog/literature/TCD-SCSS-V.20121208.873/TCD-SCSS-V.20121208.873.pdf> Also reproduced in Randell's 1971 paper, cf. n.8 below.

⁵ Brian Randell, 'From analytical engine to electronic digital computer: the contributions of Ludgate, Torres, and Bush', *IEEE Annals of the History of Computing* 4:4 (1982), 327-41.

⁶ Otherwise referred to here as 'sequence-controlled', i.e. 'program-controlled' or 'programmable', cf. n.1 above, a core concept for modern computers.

⁷ 'Conditional-branching' in modern terminology, a critical concept for modern computers.

⁸ Brian Randell, 'Ludgate's analytical machine of 1909', *The Computer Journal* 14:3 (1971), 317-26. For Randell's 1982 paper cf. n.5 above.

⁹ D. Riches. 'An analysis of Ludgate's machine leading to the design of a digital logarithmic multiplier' (unpublished undergraduate project report), Dept. Electrical and Electronic Engineering, University College (Swansea), Jun. 1973. Available at cf. n.14 below.

¹⁰ Brian Randell, 'Ludgate, Percy', *Dictionary of Irish Biography* (9 vols, Cambridge, 2009). Available at: <https://www.dib.ie/biography/ludgate-percy-a4912>

¹¹ Jim Byrne, 'Percy E. Ludgate (1883-1922): Skibbereen-born computer pioneer', *Skibbereen and District Historical Society Journal* 7 (2011), 72-80.

¹² The Percy E. Ludgate prize in Computer Science is awarded annually to the student who submits the best project in the senior year of the Moderatorship in Computer Science at Trinity College Dublin.

An investigation was initiated in 2016, under the aegis of The John Gabriel Byrne Computer Science Collection,¹³ aimed at fully exploring and documenting Ludgate's life and work.¹⁴ To that end, information relating to Ludgate's own life and early career, his close family members and their children, and his ancestors back to the early eighteenth century, domestic situation, legal issues, and 1909 paper submission, have all been examined, and one important discovery has been made concerning his family. Moreover, joint outreach activities with the Ludgate Hub,¹⁵ both in newspapers¹⁶ and at the West Cork History Festival,¹⁷ led to a second very significant discovery, that of the first known contemporary explanatory drawing of part of Ludgate's machine. As a result, it has been possible to gain a new depth of understanding of key mechanisms within his machine,¹⁸ and to attempt to codify this,¹⁹ even though his extensive set of drawings (which he stated, in both his 1909 and 1914 papers, that he had made) has never been found. It is now possible to provide a greatly expanded summary of what is known of the family, life and work of Ludgate, giving a whole range of new material (all older material from Randell's 1971 paper is explicitly identified to clearly distinguish it from recent research).

In his 1971 investigations Randell established contact with one of Ludgate's accountancy colleagues, who provided a limited amount of information. But the great majority of what was discovered then of Ludgate's family and life was obtained from just one person, his niece Violet Ludgate, who Randell stated 'made extensive efforts herself to trace further possible sources of information'. Nonetheless the family details uncovered related just to Percy Ludgate's parents and siblings but even missed his sister. Percy Ludgate's paternal ancestors have now been traced to the early 1700s, when Matthew and Mary Ludgate (Percy's paternal great-great-grandparents) are believed to have leased Marble Hill Farm, in the townland of

¹³ The John Gabriel Byrne Computer Science Collection at Trinity College Dublin, some 3000 items, holds a wealth of literature (including original offprints of Lovelace's 1843 monograph and of Ludgate's 1909 paper), plus a wide range of computers, calculating machines, slide rules, and computer software, and is recorded in the Schedules to the Statutes as being among the treasures of the College. Copies (in most cases original) of all the known literature and records relating to Ludgate are now held within this Collection. The catalogue is available at: <https://www.scss.tcd.ie/SCSSTreasuresCatalog/>

¹⁴ Ludgate folder at Trinity College Dublin. Available at: <https://www.scss.tcd.ie/SCSSTreasuresCatalog/miscellany/TCD-SCSS-X.20121208.002/> For a more mobile-friendly interface to selected Ludgate folder contents, see: <https://www.scss.tcd.ie/SCSSTreasuresCatalog/ludgate/> Copies of most of the documents cited in this paper are available at this folder.

¹⁵ An e-commerce hub opened in 2016 in Ludgate's birthplace Skibbereen, see: Noel Baker, 'Potential €37m impact of digital life on Skibbereen', *Irish Examiner*, 5 Nov. 2015, 7.

¹⁶ David Forsythe, 'Could WW1 have ended Ludgate's computer dreams?' *The Southern Star*, 27 Jul. 2019, 11; Kevin O'Neill, 'West Cork's own computer pioneer', *Cork Examiner*, 6 Aug. 2019, 2.

¹⁷ Brian Coghlan, 'An exploration of the life of Percy Ludgate', *West Cork History Festival* (10 Aug. 2019).

¹⁸ Brian Coghlan, Brian Randell, Paul Hockie, Trish Gonzalez, David McQuillan, Reddy O'Regan, 'Investigating the work and life of Percy Ludgate', *IEEE Annals of the History of Computing* 43:1 (2021), 19-37.

¹⁹ Brian Coghlan, 'Percy Ludgate's analytical machine'. Available at cf. n.14 above.

Scarragh, Kilshannig, three miles west of Mallow, see Pl. I.²⁰



PL. I—The eighteenth-century farmhouse (with 4ft-thick walls) of Marble Hill Farm, Kilshannig, Co.Cork (Image courtesy of The John Gabriel Byrne Computer Science Collection).

Matthew appears in the 1766 religious census for Kilshannig.²¹ The baptisms, burials and marriages of his descendants (see Fig. 1) are recorded in Mallow Church of Ireland records, which began in 1731. A very extensive family tree of about 100 descendants of Matthew and Mary can be constructed from these records.²² Of these, their son John and grandson Robert (paternal great-grandfather and grandfather of Percy) established their own farms nearby in the townland of Kilshannig.²³

Ludgate's maternal ancestors have also been traced, mostly to the eighteenth century, but less comprehensively, again see Fig. 1. It is not known where his paternal grandmother Suzanna Willis was born. His maternal grandfather Thomas McMahon was born in Co.Armagh, and his maternal grandmother Frances Reed was probably born in south-west Co. Cork.²⁴

²⁰ Brian Coghlan, Personal communication with owner of Marble Hill Farm (Aug. 2019).

²¹ National Archives of Ireland (NAI), *Religious Census 1766 for Kilshannig, Cloyne*, Return no. 1123 (transcript), MS 5036(a).

²² 'Percy E. Ludgate prize in Computer Science'. Available at cf. n.14 above. This is the primary biographical and genealogical reference document. For genealogy, refer specifically to sections: (a) *Family tree of Percy Ludgate's wider Ludgate relations*; (b) *Ancestors of Percy Edwin Ludgate*; (c) *Ancestors of Barbara Hopkins*; (d) *Ancestors of Eileen Mary Ludgate*.

²³ *Griffith Valuation, Parish of Kilshannig*. Available at: <http://www.askaboutireland.ie/griffith-valuation/>

²⁴ 'Percy E. Ludgate prize in Computer Science', cf. n.22 above.

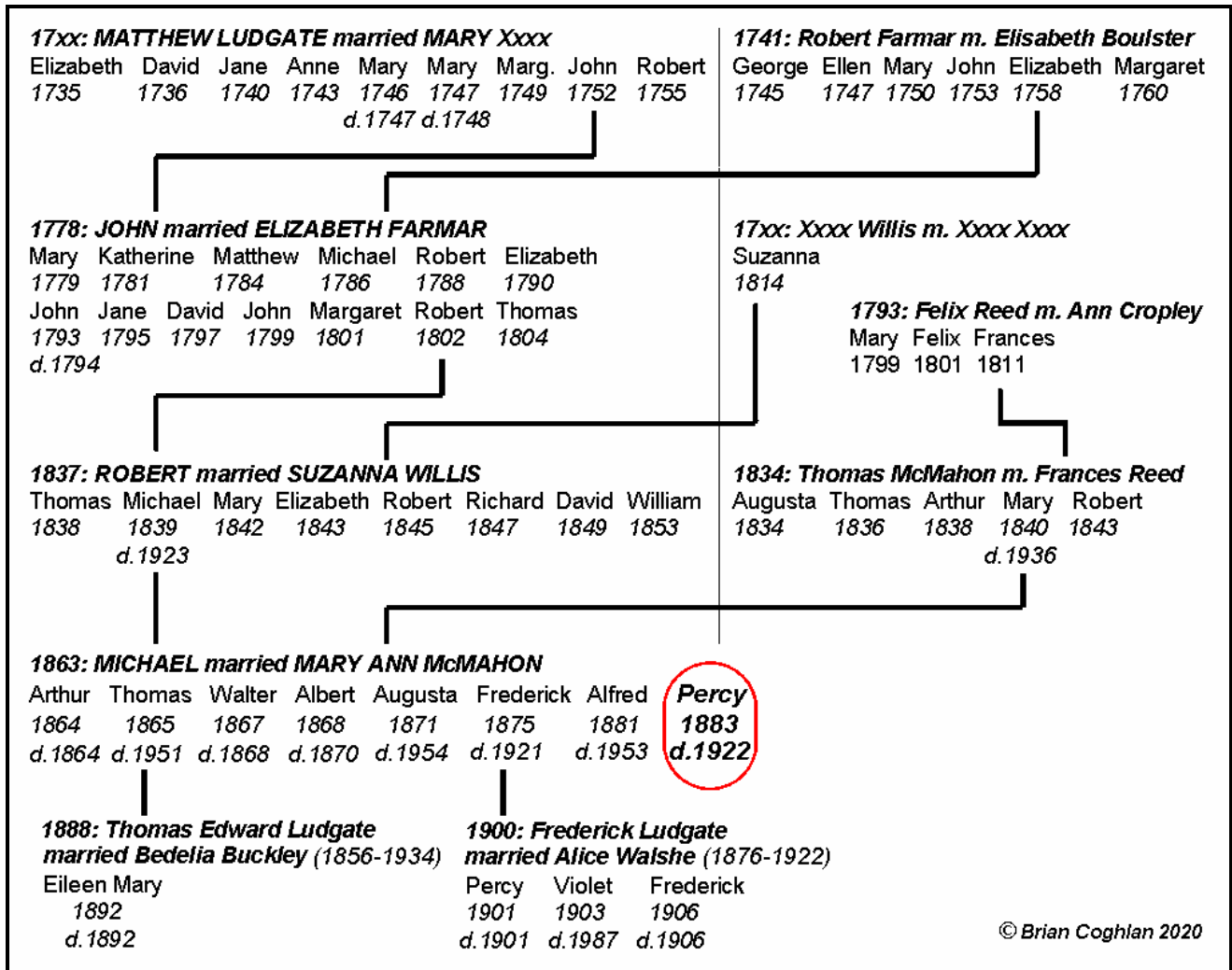


FIG. 1—Summary Family Tree of Michael Ludgate and Mary Ludgate née McMahon (Image courtesy of The John Gabriel Byrne Computer Science Collection).

Via his parent's siblings, and his own siblings, Percy had a large number of close relatives and in-laws. In total on his paternal side he had 5 uncles, 2 aunts, and at least 7 cousins, while on his maternal side he had 3 uncles, 1 maternal aunt, and perhaps cousins. In addition his sister-in-law Bedelia (Bridget) née Buckley, who was from Douglas, Cork, had eleven siblings, and his other sister-in-law Alice (Alicia) née Walshe from Dublin City had two siblings. In total his close relatives and in-laws included fifteen of his parent's generation, plus at least twenty of his own generation, all born in the nineteenth century, almost all in the Victorian age of empire and accelerating scientific sophistication.

The eighteenth century and nineteenth century through which these ancestors of Percy Ludgate lived were two very different scientific eras in the U.K. The eighteenth century was the last in which science was primarily conducted by financially independent individuals, and when the more deductive scientific method

of ‘natural philosophy’ held sway, whereby derived facts were logically deduced from existing ‘knowledge’.²⁵ From the early nineteenth century a more inductive and disciplined scientific method based on precepts outlined by Francis Bacon progressively dominated, whereby collected evidence could by induction engender falsifiable theories and thereby ‘new knowledge’ until proven otherwise.²⁶

Charles Babbage was closely involved in this change, which was passionately promoted in the first half of the nineteenth century by Babbage, William Whewell, John Herschel and Richard Jones (members of the so-called ‘Philosophical Breakfast Club’).²⁷ In 1812, Babbage, Herschel and George Peacock established the Analytical Society to pursue (successfully) the move from Newton’s to Leibniz’s notation for calculus. In 1820, Babbage, Herschel and others founded the Royal Astronomical Society. From 1822, Babbage began designing his Difference Engine No.1.²⁸ In 1827, Babbage, with help from an Irish friend,²⁹ Thomas Colby, published a much improved table of logarithms.³⁰ In 1831, William Harcourt, David Brewster, Babbage, Whewell and others founded the British Association for the Advancement of Science (Whewell coined the term ‘scientist’ at its 1833 meeting). From 1834, Babbage began designing his Analytical Engine.³¹ In 1834, Babbage, Jones, Whewell and others founded the Royal Statistical Society. In 1837, Babbage published his controversial *The Ninth Bridgewater Treatise*, employing difference engine concepts in a discussion of how science and religion interrelate.³² And from 1828-39, he held the Lucasian Professorship of Mathematics at Cambridge, the prestigious chair that Isaac Newton once held. Herschel and Whewell were reportedly the more influential scientists of their generation, but in relation to computing, Babbage’s contribution was seminal; he was the first person to design a sequence-controlled computer, his Analytical Engine.

Babbage produced a large number of drawings, but they are all two-dimensional. The most evocative visual representations of his Analytical Engine, and in particular its scale, are those produced by Sydney

²⁵ Simon Schaffer, ‘Scientific discoveries and the end of Natural Philosophy’, *Social Studies of Science* 16:3 (1986), 387-420.

²⁶ William Whewell, *History of the Inductive Sciences, from the earliest to the present time* (3 vols. London, 1837).

²⁷ Laura J. Snyder, *The Philosophical Breakfast Club: four remarkable friends who transformed Science and changed the world* (New York, 2011).

²⁸ Babbage was also the first person to design what he called a ‘Difference Engine’, a large machine consisting of a number of linked adding mechanisms capable of calculating and printing mathematical tables of polynomial functions.

²⁹ Babbage had a number of associations with Ireland, see: *Irish interactions with Charles Babbage regarding his Difference Engines and Analytical Engine*. Available at: <https://www.scss.tcd.ie/SCSSTreasuresCatalog/miscellany/TCD-SCSS-X.20121208.001/TCD-SCSS-X.20121208.001.pdf>

³⁰ Charles Babbage, *Table of the logarithms of the natural numbers from 1 to 108000* (London, 1827).

³¹ Lovelace, ‘Sketch of the analytical engine’, cf. n.2 above.

³² Charles Babbage, *The Ninth Bridgewater Treatise - A fragment* (London, 1837). Available at: https://victorianweb.org/science/science_texts/bridgewater/intro.htm

Padua, for her graphic novel *The Thrilling Adventures of Lovelace and Babbage*,³³ and also the image created by her for this paper, which is reproduced within Fig. 2. His Analytical Engine was designed in four principal parts: the arithmetic unit, storage, input and output, and the sequencing mechanism. The arithmetic unit, which he called the Mill, was surrounded by the Input, the Output and the Sequencing Mechanism. The Mill was built like a sponge cake, each layer capable of representing and acting on one digit of a decimal number. Babbage planned to have 50-digit numbers, so there were fifty layers, stacked one above the other. Inside, there was a large circular ring gear that engaged with the little gears around the outside that did the calculation, controlled it, and did input and output. The ring gear was also replicated per digit. Calculations were done in the Mill based on addition. The desired sequence of operations and the relevant input of numbers were defined via perforated cards based on those used in Jacquard weaving looms.³⁴ The Storage was also layered, and in columns representing 50-digit numbers. In Babbage's *circa* 1843 plans each column stored two numbers.³⁵ Ada Lovelace's 1843 monograph states: 'In the Analytical Engine there would be many more of these columns, probably at least two hundred'.³⁶ For each number there were fifty little gears, each capable of rotating so as to represent a decimal digit. In the c.1843 plans the Storage extended away from the Mill, and added considerably to the footprint of the engine.

Babbage's planned engine was entirely mechanical, and would have needed precision engineering (but contemporary precision may have been sufficient).³⁷ It was a very novel and ambitious concept. It is worth quoting his son Henry's words: 'it is to be noted that the engine is designed for analytical purposes, and it would be like using the steam hammer to crush the nut, to use the Analytical Engine to solve common sums in arithmetic'.³⁸ The vast expense and physical practicalities resulted in only a small portion of the Analytical Engine ever being built. Henry continued: 'I believe that the present state of the design would admit of the engine being executed in metal ... I see no hope of any Analytical Engine, however useful it might be, bringing any profit to its constructor ... The History of Babbage's Calculating Machines is sufficient to damp the ardour of a dozen enthusiasts'.

³³ Sydney Padua, *The thrilling adventures of Lovelace and Babbage: the (mostly) true story of the first computer* (London, 2016).

³⁴ James Essinger, *Jacquard's web: how a hand-loom led to the birth of the information age* (Oxford, 2007).

³⁵ Tim Robinson, Personal communications with Brian Coghlan and Brian Randell (Dec. 2020).

³⁶ Lovelace, 'Sketch of the analytical engine', 701, cf. n.2 above.

³⁷ Doron Swade, *The cogwheel brain: Charles Babbage and the quest to build the first computer* (London, 2000). In 1991 the London Science Museum built Babbage's Difference Engine No.2 from its 1846-9 drawings, using only contemporary engineering practices and tolerances.

In the subsequent Victorian era, others constructed machines that are relevant to the history of computing. From 1837-43 the Swedish father and son Scheutz constructed the first of several difference engines, and a small number of other inventors followed their example.³⁹ In 1870 at the Royal Society, Jevons exhibited his 'Logic Piano' performing logical inferences.⁴⁰ In 1884, Hollerith filed a patent for compiling statistics using punched cards,⁴¹ the basis for the tabulating machines supplied by his company (an ancestor of IBM) for the 1890 Census of the U.S.A. But none had the scope or the capability of Babbage's machine, which Lovelace stated: 'holds a position wholly of its own'.⁴² It is into this very mechanical and increasingly mathematical scientific era that Percy Ludgate was born.

II. PERCY LUDGATE'S FAMILY AND EARLY LIFE

Percy's father Michael Edward Ludgate (1839-1923),⁴³ who was born in Kilshannig, joined the North Cork Militia in 1857 with two other members of the Ludgate family.⁴⁴ In 1858, the militia was relocated to Kent where the Ludgates transferred to the 21st Regiment of Foot in the regular army. Within two weeks Michael was promoted to Corporal and one year later to Sergeant Musketry Instructor. He married Mary Ann McMahon (1840-1936) in 1863 at Winchester Barracks. Mary was born in Iden, Sussex, but also was from an Anglo-Irish military family, with roots in counties Antrim, Armagh and Suffolk, the Suffolk branch being Navy rather than Army. Michael served a typical military life at a variety of locations, including India (taking his family with him), Aden, Hythe, Chatham, Gravesend and Winchester. He was ultimately assigned to the 60th Regiment of Foot as a Master Sergeant Instructor, attached to the School of Musketry,⁴⁵ an army corps responsible for testing small arms including automatic weapons. In 1876, he retired to Skibbereen in County Cork, where Percy's brother Alfred was born in 1881. Michael's service record shows his pension being collected there in 1882, and late in that year he advertised, in the *Skibbereen Eagle*, his services as an after-hours shorthand tutor.⁴⁶ It is possible he learned shorthand in the Army, since

³⁸ Major-General H. P. Babbage, 'The Analytical Engine', *Proceedings of the British Association* (paper read at Bath, 12 Sep. 1888). Also included in: H. P. Babbage (ed.), *Babbage's calculating engines: being a collection of papers relating to them, their history, and construction* (London 1889), 331-8. Available at: <https://www.fourmilab.ch/babbage/hpb.html>

³⁹ Michael R. Williams, 'The difference engines', *The Computer Journal* 19:1 (1976), 82-9.

⁴⁰ William Stanley Jevons, 'On the mechanical performance of Logical Inference', *Philosophical Transactions of the Royal Society* 160 (1870), 497-518. Available at: <https://royalsocietypublishing.org/doi/pdf/10.1098/rstl.1870.0022>

⁴¹ Herman Hollerith, *An electrical tabulating system*, School of Mines Quarterly, Columbia University, 10:3 (1889), 238-55. Reprinted in Randell, B. (ed.), *The origins of digital computers: selected papers* (Berlin, 1982).

⁴² Lovelace, 'Sketch of the analytical engine', 697, cf. n.2 above.

⁴³ For details of service records, careers, births, marriages and deaths referred to in Section II, see: 'Percy E. Ludgate prize in Computer Science', cf. n.22 above, especially sections: *Ancestors of Percy Edwin Ludgate*; *Ancestors of Barbara Hopkins*; *Ancestors of Eileen Mary Ludgate*.

⁴⁴ Major J. Douglas Mercer. *Record of the North Cork regiment of militia, with sketches extracted from history of the times in which its services were required, from 1793 to 1880* (Dublin, 1886).

⁴⁵ Renamed 'Corps of the Small Arms School' in 1919.

⁴⁶ 'M.E. Ludgate', *Skibbereen Eagle*, 16 Sep. 1882, 3; 'M.E. Ludgate', *Skibbereen Eagle*, 18 Nov. 1882, 4.

his service record shows his profession as a clerk. He and Mary had at least eight children, only five of whom survived: Thomas (b.1865 Winchester), Augusta (b.1871, Bellary, India), Frederick (b.1875 Gravesend), Alfred (b.1881 Skibbereen), and the eighth and youngest child, Percy, who was born on 2 August 1883 at Townshend Street, Skibbereen (see Pl. II). After that there is a period of seven years during which the family's whereabouts and livelihoods largely elude discovery. Only the whereabouts of Percy's brother Thomas have been established, and only late in this period. In 1888, Thomas married Bedelia Bridget Buckley at St. Peter and St. Paul's Church in Cork. They settled at Roseville, 80 Sundays Well, a fine two storey house in Cork City on the east side of the River Lee (opposite the gaol), where they remained until at least 1893.⁴⁷



PL. II—Percy Ludgate's birthplace, Skibbereen, showing the Memorial to the 1798 Rebellion (Image courtesy of *The Southern Star*).

Michael Ludgate and the remainder of his family are next recorded in *Thom's Directory* at 28 Foster

⁴⁷ Bedelia Bridget Ludgate's bridesmaid was her sister Cecilia, who married six months later to John Buckley (same surname) and settled nearby at Vista Villa, 124 Sundays Well. Cecilia gave birth to two children, Daniel b.1891 and Cecilia b.1893, but

Terrace, Dublin, firstly in 1890 as ‘Ludgate, Michael Edward, teacher of shorthand’, then in 1891 as ‘Ludgate, Michael Edward, teacher of shorthand, Ludgate, Fred, teacher of shorthand, Ludgate, Miss Augusta, teacher of shorthand’, and from 1892-8 as ‘Ludgate, Michael Edward, sons & daugh, teachers of shorthand’, indicating the evolution of a small-scale family business.⁴⁸ It had been thought that 28 Foster Terrace no longer existed, but convincing evidence has been found that No.28 was renumbered in the twentieth century as either No.46 or No.47,⁴⁹ both of which still exist, see Pl. III.



PL. III—The two potential candidates for Percy Ludgate’s first home in Dublin: (left) 47 Foster Terrace, Ballybough, Dublin, and (right) 46 Foster Terrace, Ballybough, Dublin (Images courtesy of Gerry Kelly).

It is known from school records that at age 7-8 years Percy attended St. George’s Infants School.⁵⁰ Randell’s 1971 paper states that from 8-12 years he is said to have attended St. George’s National School. His family were members of the Church of Ireland,⁵¹ and Randell’s 1971 paper also states Percy attended St. George’s Church, Temple Street, see Pl. IV.

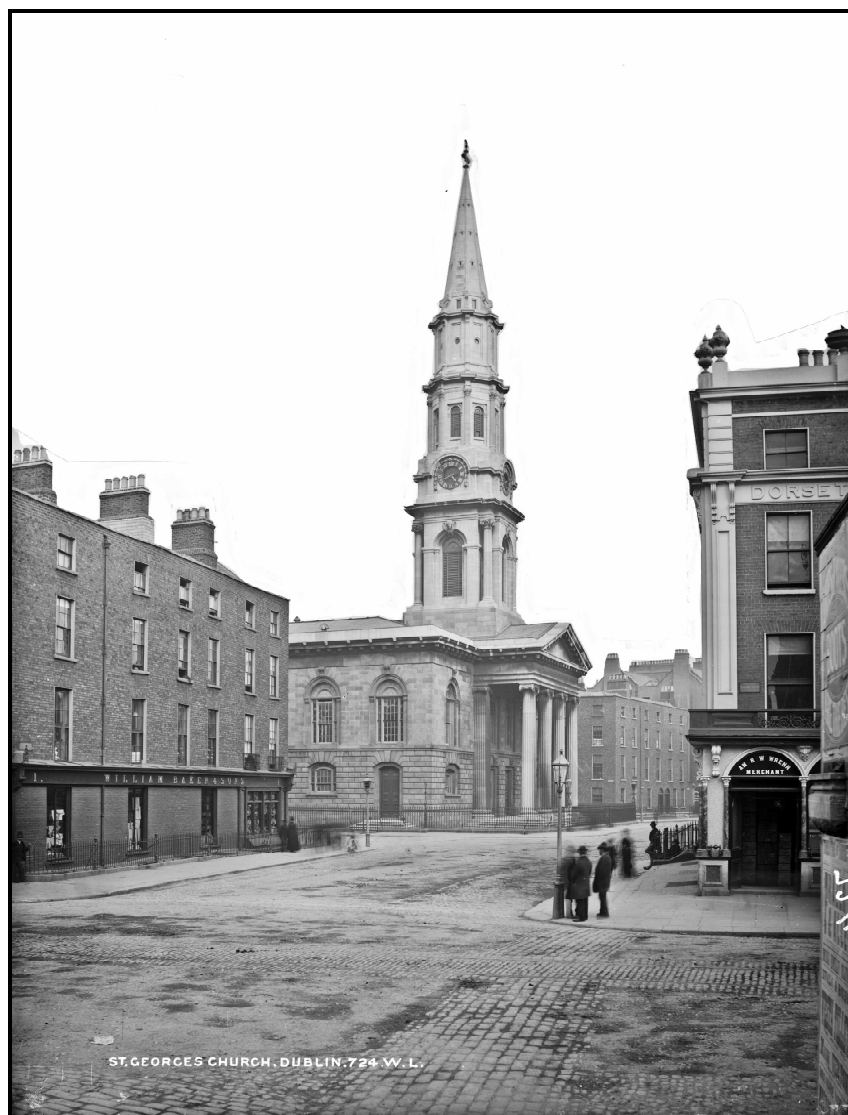
when she died at her home after the latter’s birth, her death was registered by ‘Bridget Ludgate sister present at death Rose Ville, S. Well’, so Bedelia still lived at RoseVille (80 Sundays Well) in 1893.

⁴⁸ ‘28 Foster Terrace, Ballybough, Dublin’, in *Thom’s Directory* (1890-8).

⁴⁹ Gerry Kelly, ‘46 Foster Terrace’ (9 Nov. 2019) and ‘Evidence 28 Foster Place was Renumbered’ (25 Nov. 2020).

⁵⁰ NAI, Ireland National School Registers, Roll no. 11624 (St.George’s Parish, St George’s Infants School attendance records 1890 and 1891). Percy Ludgate enrolled in Class I on 15 Sep 1890 (register entry 559) for the year ending 31 Mar. 1891, then is shown as enrolled in Class III for the year ending 31 Mar. 1892, and as leaving the infants school in May 1892.

⁵¹ NAI, 1901 *Census Returns*.



PL. IV—St. George’s Church, Temple Street, Dublin, the church that Percy Ludgate attended (Image L_ROY_0072 courtesy of the National Library of Ireland).

Percy presumably attended an as yet unidentified secondary school, as attendance was compulsory until age fourteen. In 1898, when he was aged fifteen years, *The London Gazette* published that he was appointed a ‘Boy Copyist’ in the Irish Civil Service, then a temporary post for boys aged 15-20 years old.⁵² In 1899, his family moved to 30 Dargle Road, Drumcondra (see Pl. V), in what was a new development on Dublin’s outskirts, one mile north-west of Foster Terrace.⁵³ In that year his father Michael, giving an address in Balbriggan, was imprisoned in Kilmainham Gaol for non-payment of debt (he had to choose between prison or payment of £5.2s, and opted to serve as Prisoner 1076 from 8 September 1899 to 19 October

⁵² *The London Gazette*, 22 May 1896, 3066-8; 13 July 1897, 3900-1; 14 Jan. 1898; 4 Nov. 1898, 6454-5; 19 Sep. 1902, 6029; 7 Nov. 1902, 7095; 17 Mar. 1903, 1779; 23 Aug. 1904, 5419-20 collectively are relevant to Percy Ludgate’s actual and potential career in the Civil Service.

1899).⁵⁴ The following year his brother Frederick married Alice Walshe.

The 1901 Irish Census lists Percy, his mother and a brother Alfred at 30 Dargle Road. Percy is listed as a 'Civil Servant (Boy Copyist)' in the National Education Office, while Alfred was a 'commercial clerk (engineering trade)'. Frederick and Alice are listed at 24 Dargle Road (just six doors away), with Frederick as a 'commercial traveller (chemicals)'. His father Michael is listed at 14 Quay Street, Balbriggan, seventeen miles away, perhaps suggesting a divorce, or at least a family break up. Meanwhile, his other brother Thomas and wife Bedelia had moved to 13 Mardyke, on the opposite side of the River Lee in Cork City, with Thomas listed as a land agent's cashier. His sister Augusta is recorded in the 1901 U.K. Census as a 'Deaconess/Missionary' in Liverpool.⁵⁵

In March 1903 Percy was the top Irish candidate in the Civil Service examinations for Assistant Clerkship (Abstractors).⁵⁶ At that time, the Civil Service arguably preferred classicists.⁵⁷ His ability at mathematics may not then have been of great weight, but the fact that he came first in Ireland in the Civil Service exams was proof he was strong also in classics. He passed the medical, but was not appointed to a position, while at minimum the next six ranked candidates from Dublin have been found to have been appointed to a Civil Service position.⁵⁸ The reason for this rather strange outcome is not yet known.

In August 1903 on his twentieth birthday, Percy's Boy Copyist post expired, and his short Civil Service career came to an end.⁵⁹ In the same year he seemingly began work on his Analytical Machine, since his 1909 paper, which was submitted in December 1908, states: 'I purpose to give in this paper a short account of the result of about six years' work'. It is not known why he became interested in mathematical calculations, let alone in automating them. Randell's 1971 paper stated that: 'It seems almost certain that his work on the analytical machine was a private hobby which, according to his niece, "he used to work at nightly, until the small hours of the morning".'

⁵³ '30 Dargle Road, Drumcondra, Dublin', in *Thom's Directory* (1899-1936).

⁵⁴ 'Percy E. Ludgate prize in Computer Science', cf. n.22 above, section *Ancestors of Percy Edwin Ludgate*.

⁵⁵ The National Archives (TNA), *1901 UK Census Returns*.

⁵⁶ 'London correspondence', *Weekly Irish Times*, 21 Mar. 1903, 13. Percy Ludgate was ranked the top Irish candidate, and was ranked 19 in the U.K. The next six Irish candidates were ranked 22, 25, 29, 33, 35 and 46. All came from Dublin. Only the rankings of the top 50 candidates were published.

⁵⁷ Charles Percy Snow, *The Rede lecture (1959): The two cultures* (Cambridge, 1993).

⁵⁸ Gerry Kelly, 'Evidence Percy Edwin Ludgate was Passed Over' (23 Nov. 2020).

⁵⁹ Gerry Kelly, 'Percy Edwin Ludgate – Irish Civil Service' (11 Mar. 2013).



PL. V—30 Dargle Road, Drumcondra, where Percy Ludgate did his work on his Analytical Machine (Image courtesy of Michael Mongan).

In October 1904 Percy Ludgate passed the Civil Service exams for Second-Division Clerkships in the Civil Service,⁶⁰ but failed the medical, and therefore was not appointed to a position. In February 1905, the ‘Case of Mr. Percy Ludgate – Irish Civil Service’ was raised in the House of Commons, Westminster, during Questions in the House. The petition was for a new medical examination with a view to his being certified for one or other of the positions for which he had passed exams. He got a negative response from the Financial Secretary of the Treasury, Victor Cavendish MP: ‘As nearly a year had elapsed since Mr. Ludgate’s medical examination for an assistant clerkship, it was necessary to re-examine him before issuing him a certificate for a second-division clerkship. The result of the medical examination proving unsatisfactory the Civil Service Commissioners were unable to grant a certificate for either position. The medical requirements are practically the same in both cases’.⁶¹

⁶⁰ Second-Division is the next grade. The examination was announced in *The London Gazette* (23 Aug. 1904), 5419-20. The result is given in cf. n.61 below.

⁶¹ *Hansard* 141 (20 Feb. 1905). Available at: <https://api.parliament.uk/historic-hansard/commons/1905/feb/20/irish-civil-service-case-of-mr-percy>

The MP for Drumcondra was John Joseph Clancy,⁶² a highly educated nationalist politician and King's Counsel (KC), but the MP that took Ludgate's case, Timothy Charles Harrington,⁶³ was MP for Dublin Harbour. He was Lord Mayor of Dublin in 1901–4, owner of *United Ireland* and *Kerry Sentinel* newspapers, a Corkman and member of the 'Bantry band' of prominent nationalist politicians, and also a highly educated KC.⁶⁴ That he took the case of a non-constituent denied a Civil Service post after a failed medical is unusual. It is possible that there was a prior relationship, as Percy's uncle William Ludgate,⁶⁵ and William's son Robert,⁶⁶ worked for a newspaper in Cork, or that it was simply a reaction to the rejection of Percy's apparent capacity for the role.

III. PERCY LUDGATE'S YEAR OF ACHIEVEMENT

In December 1908 Ludgate submitted his paper 'On a Proposed Analytical Machine' to the Royal Dublin Society, and in April 1909 it was published in their Scientific Proceedings. In July 1909 a detailed review of the paper by Prof. Charles Vernon Boys was published in *Nature*.⁶⁷ Percy Ludgate's paper was a significant achievement for a mere clerk to a corn merchant. The Royal Dublin Society's Publications Committee included several fellows of the Royal Society and numerous professors, so Ludgate's proposed machine became known to an elite cohort of scientists.

The minutes of the Publications Committee (a function of the Science Committee) show the review process his 1909 paper went through.⁶⁸ The paper's first reviewer, Prof. A.W. Conway,⁶⁹ suggested it was sent to Prof. Boys,⁷⁰ presumably for a more expert review (Boys was an acknowledged expert on calculating machines). The minutes say 'Registrar to communicate Prof Boys remarks to the author & ask him to emphasize the points which he considers important', and later 'Read Mr. Percy Ludgate's letter in reply to the suggestion made to him', presumably by Prof. Boys. The paper says at the start 'Communicated

⁶² 'Obituary of J. J. Clancy KC', *Irish Independent*, 26 Nov. 1928, 7.

⁶³ 'Death of Mr T C Harrington, MP', *Kerry Sentinel*, 16 Mar. 1910, 3.

⁶⁴ 'Harrington, Timothy Charles', *Dictionary of Irish Biography* (2009). Available at: <https://www.dib.ie/biography/harrington-timothy-charles-a3816>

⁶⁵ William Joseph Ludgate, available at: https://www.scoop-database.com/bio/ludgate_william_joseph_1

⁶⁶ Robert Willis Ludgate, available at: https://www.scoop-database.com/bio/ludgate_robert_willis

⁶⁷ C.V. Boys, 'A new analytical engine', *Nature* 81 (Jul. 1909), 14-15. Also reproduced in Randell's 1971 paper, cf. n.8 above.

⁶⁸ *Minutes of the Royal Dublin Society's Publications Committee for 1908-1909* (Dublin, 1908-9).

⁶⁹ Conway later became the first Chairman of the Dublin Institute for Advanced Studies, President of the Royal Irish Academy, and President of University College Dublin. His descendants have recently been located, but his personal papers have not been found.

⁷⁰ Boys (commonly known as C.V. Boys) had already been a Fellow of the Royal Society for twenty years, had recently been President of the Röntgen Society, soon became President of the Physical Society, and later was knighted. His descendants have been located, but his personal papers have not been found.

by Prof. A.W. Conway', and this phrase appears in notices of the presentation on 23 February 1909,⁷¹ as well as in the annual report of the Committee on Science,⁷² so Conway either communicated the notices or gave the presentation; likely the former as he is not specifically thanked for any such presentation, whereas the paper says: 'I desire to record my indebtedness to Professor C.V. Boys FRS for the assistance which I owe to his kindness in entering into correspondence with me'.

Percy Ludgate is imagined in Fig. 2 seated at a table with his desktop-sized Analytical Machine in front of him, alongside Babbage in front of his large engine.

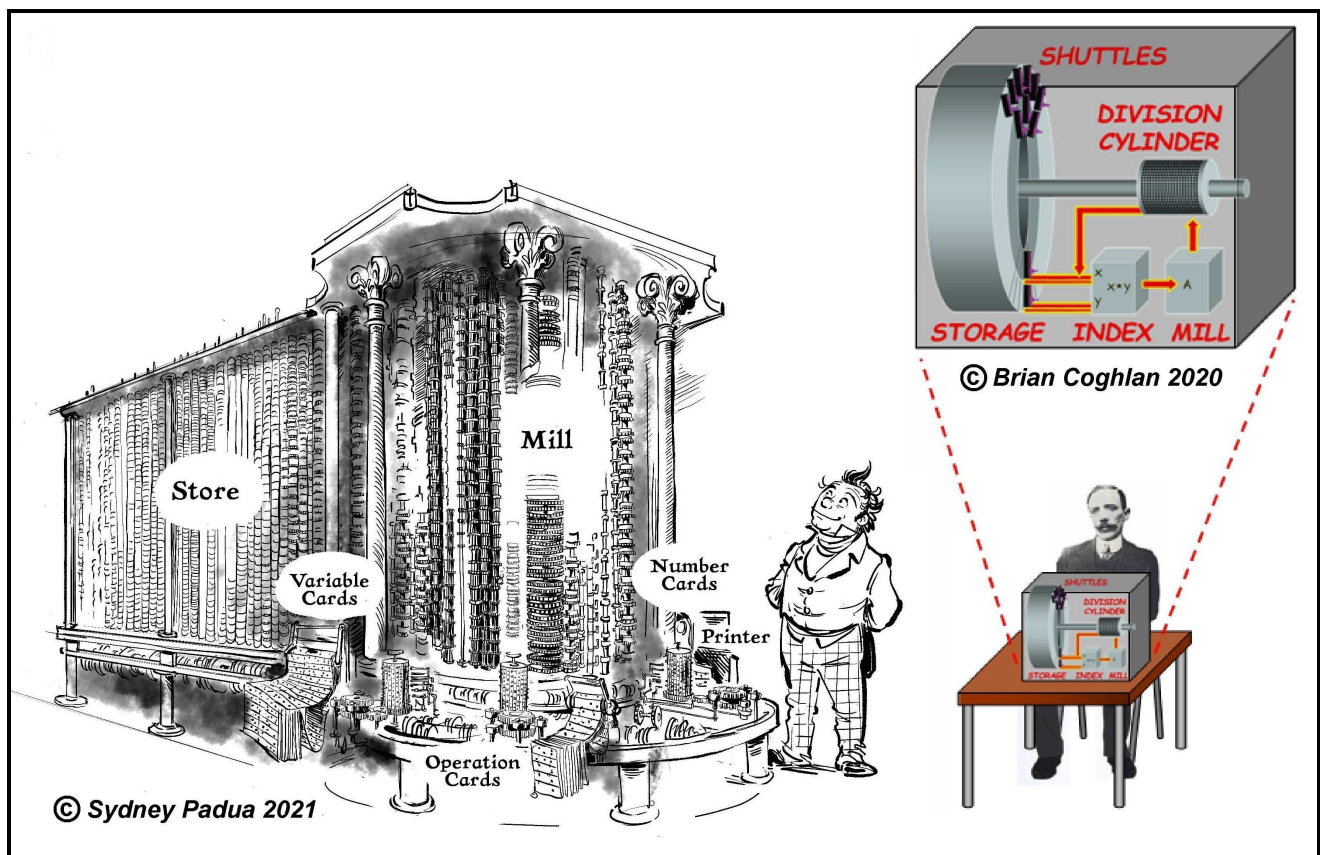


FIG. 2—(left) Charles Babbage imagined in front of his Analytical Engine (Image courtesy of Sydney Padua). (right) Percy Ludgate imagined at his Analytical Machine (Image courtesy of The John Gabriel Byrne Computer Science Collection; portrait of Percy Ludgate, image courtesy of Brian Randell).

The huge difference in the Babbage and Ludgate designs adds considerable credibility to Ludgate's statement that he did not know of Babbage's ideas in advance. He included paragraphs on Babbage that

⁷¹ 'Communications', *Freeman's Journal*, 23 Feb. 1909, 6; 'R.D. Society Scientific Meeting', *Irish Independent*, 24 Feb. 1909, 6.

⁷² *Proceedings of the Royal Dublin Society*, 96 (11 Nov. 1909 to 10 Mar 1910). The Report of the Committee on Science and its Industrial Applications says: 'following communications were received ... 23 Feb. 1909 ... "On a proposed Analytical

surround the body of his paper, together with references within the body, but did not state on what date he was first aware of those ideas. To quote from Ludgate's 1909 paper: 'In order to prevent misconception, I must state that my work was not based on Babbage's results—indeed, until after the completion of the first design of my machine, I had no knowledge of his prior efforts in the same direction. On the other hand, I have since been greatly assisted in the more advanced stages of the problem by, and have received valuable suggestions from, the writings of that accomplished scholar'.

Ludgate's 1909 paper clearly shows his design also had four principal parts: the arithmetic unit, storage, input and output, and a sequencing mechanism. Like Babbage's, Ludgate's arithmetic unit had a Mill, which performed addition in the same way. But Ludgate introduced a brand new concept, which he called an 'Index', to do multiplication based on what Prof. Boys delightfully termed 'Irish Logarithms'.⁷³ Thus the core of his arithmetic unit did not just do additions; it did multiply-accumulation (MAC), i.e. multiplication followed by addition to any previous result in the Mill, the first computer arithmetic unit to do so.⁷⁴ Ludgate also proposed mechanisms to do division and logarithms, again introducing a new concept, division by convergent series seeded with an estimate from a mechanical table of initial values.

The arithmetic unit could be stepped through a sequence of operations either manually or under automatic control, the latter using perforated 'formula-paper' to define the desired sequence of operations and perforated 'number-paper' to provide the required set of input numbers, while for output a printer could both print on and perforate paper. Ludgate's scheme to control sequencing was closer to that of modern computers than Babbage's, in that each line of perforations in the formula-paper identified the operation and its operands, whereas Babbage's scheme of separate variable (and combination) cards and operation cards was significantly more complicated. Ludgate's scheme also simplified the provision of the crucial facility of changes to sequencing behaviour if defined conditions, e.g. negative or zero Mill contents, occurred.

His Storage system was based around two concentric cylinders that held numbers in shuttles. In each shuttle there were 21 rods, one for the sign, and one per digit of a twenty-digit number. The rods protruded from the shuttle between one and ten units. In order to access a number, the shuttle was rotated to align with the Index. If variable C was in an outer shuttle and variable D was in an inner shuttle, then to perform a

Machine," by Percy E. Ludgate. (Communicated by Professor A. W. Conway. M.A.).' Possibly non-member's papers were '(Communicated by)' members, as those so listed are exclusively by non-members.

⁷³ Brian Coghlan, 'Percy Ludgate's logarithmic indexes'. Available at cf. n.14 above.

⁷⁴ MAC is important in signal processing, e.g. in radar and astronomy, and more recently in deep artificial intelligence (deep-AI).

calculation $C * D$, each of the storage cylinders was rotated to align those shuttles with the Index. Then the shuttles were brought forward along races to engage with the Index,⁷⁵ and the calculation proceeded with a multiply $C * D$ followed by accumulation of partial products in the Mill, following which the shuttles returned to their cylinders. The result in the Mill could then be written to a new shuttle and stored somewhere else in one or both of the cylinders. This was a very novel form of storage, and completely new. Ludgate did not discuss the methods of selecting a shuttle, and neither Babbage or Ludgate discussed the need for, let alone the methods of, selecting a shuttle based on the result of prior calculations.⁷⁶

Only a few machine features are described in Ludgate's 1909 paper, almost everything about its construction is unknown. The 'many drawings of the machine and its parts' that Ludgate states he prepared appear not to have survived (or if they have, they have not been located). But two recently identified contemporaneous articles, one in *English Mechanic and World of Science*,⁷⁷ derived from the other in *Engineering*,⁷⁸ are of significant assistance in this respect. They contain the first known diagram illustrating the operation of the Index. Fig. 3 shows an annotated version of this diagram. The text of the articles appeared at first sight to contradict Ludgate's 1909 paper, but subsequent analysis suggested that the text, and the diagram, were probably provided by Ludgate; in fact treating Ludgate's paper and these articles (with their diagram) as equally valid reveal details of the probable working of the Index that would have been very hard to arrive at with only Ludgate's 1909 paper.⁷⁹

⁷⁵ A 'race' is a groove or guide along which an object (typically ball or roller bearings, in this case a shuttle) can be moved.

⁷⁶ 'Dynamic' selection in modern terminology, considered to be a key requirement for a general-purpose computer.

⁷⁷ Engineering (attribution), 'A proposed analytical machine', *English Mechanic and World of Science* 90:2319 (1909/10, 3 Sep. 1909), 111. Discovered by Ralf Buelow, and image provided by Eric Hutton 19 Dec. 2019. Reproduced in Coghlan, 'Percy Ludgate's analytical machine', cf. n.19 above.

⁷⁸ 'A proposed analytical machine', *Engineering* (20 Aug. 1909), 256-7. Both discovery and provision of the image by Jade Ward, Univ.Leeds Library, on 14 Jan. 2020. Reproduced in Coghlan, 'Percy Ludgate's analytical machine', cf. n.19 above.

⁷⁹ Coghlan, 'Percy Ludgate's analytical machine', cf. n.19 above.

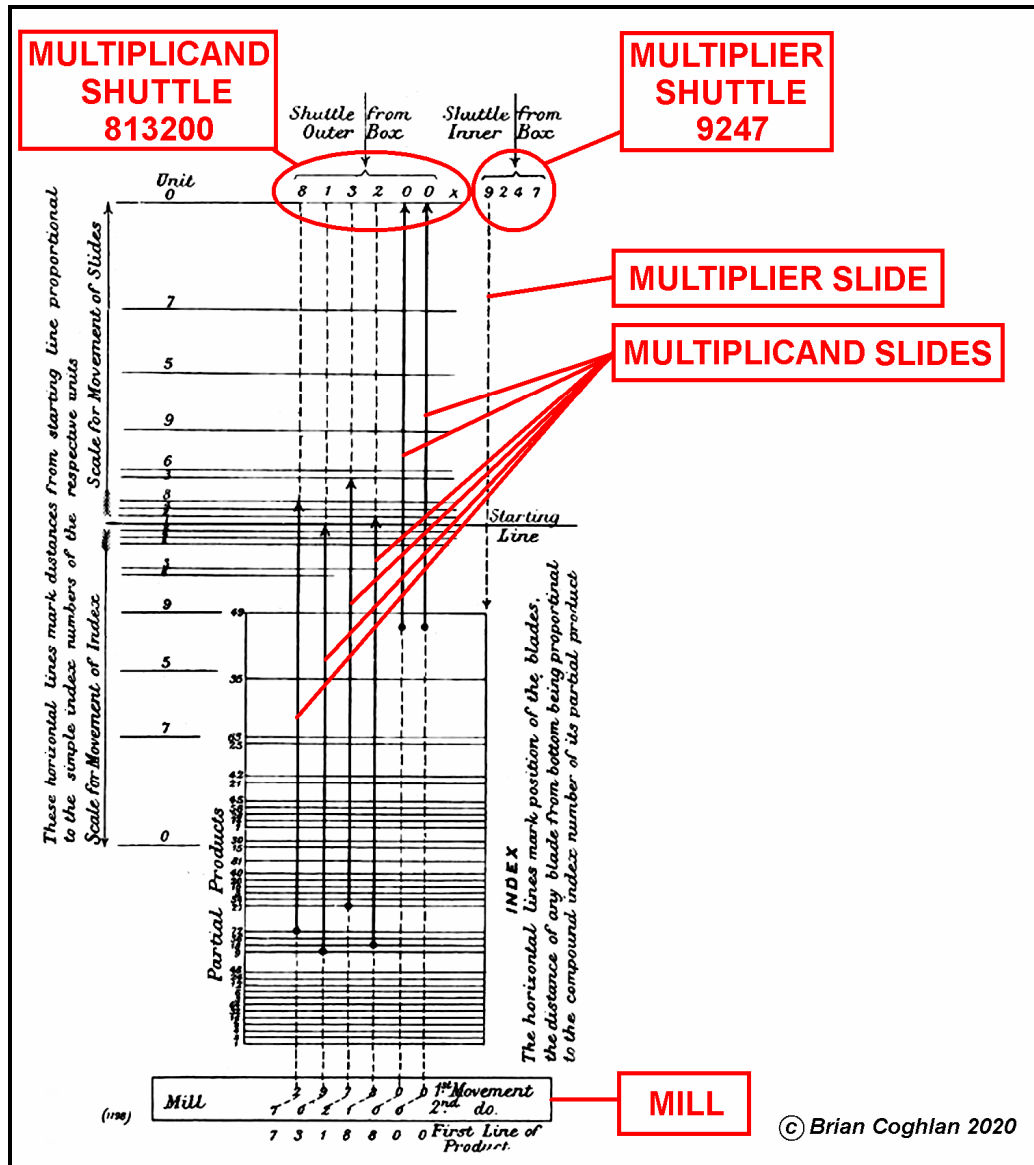


FIG. 3—Annotated version of the diagram from Engineering, 20 August 1909, pp.256-7 (Image courtesy of The John Gabriel Byrne Computer Science Collection).

The Index employed logarithmic index 'slides'. The profiles of these slides, portrayed in Fig. 4,⁸⁰ were such that they obey a logarithmic law that enables them to be used to convert multiplication into addition, i.e. $\log(j*k) = \log(j) + \log(k)$. By means of these slides the decimal digits of numbers were represented in a logarithmic form as lengths, so that multiplication could be achieved by addition using simple linear motion. There were twenty identical multiplicand slides, one for each decimal digit. There was just one (opposing) slide for one digit of the multiplier, so the multiplication took place iteratively (one multiplier digit per iteration) with twenty multiplicand digits being simultaneously multiplied by that one multiplier

⁸⁰ Presumed shape based on: David McQuillan, *The feasibility of Ludgate's analytical machine*. Available at: <http://www.fano.co.uk/ludgate/Ludgate.html>

digit.⁸¹ The protruding rods, representing the digits to be multiplied, governed the positions into which the opposing slides could be moved, causing the ends of the slides to increase in overlap from their starting position. The extent of the increase in overlap constitutes the ‘logarithm’ that represents the resulting two-digit partial product. This digital ‘logarithmic’ mechanism is therefore very different from an analog logarithmic slide rule; they do have the addition of logarithmic quantities (lengths) in common, but the logarithms are of a very different form.

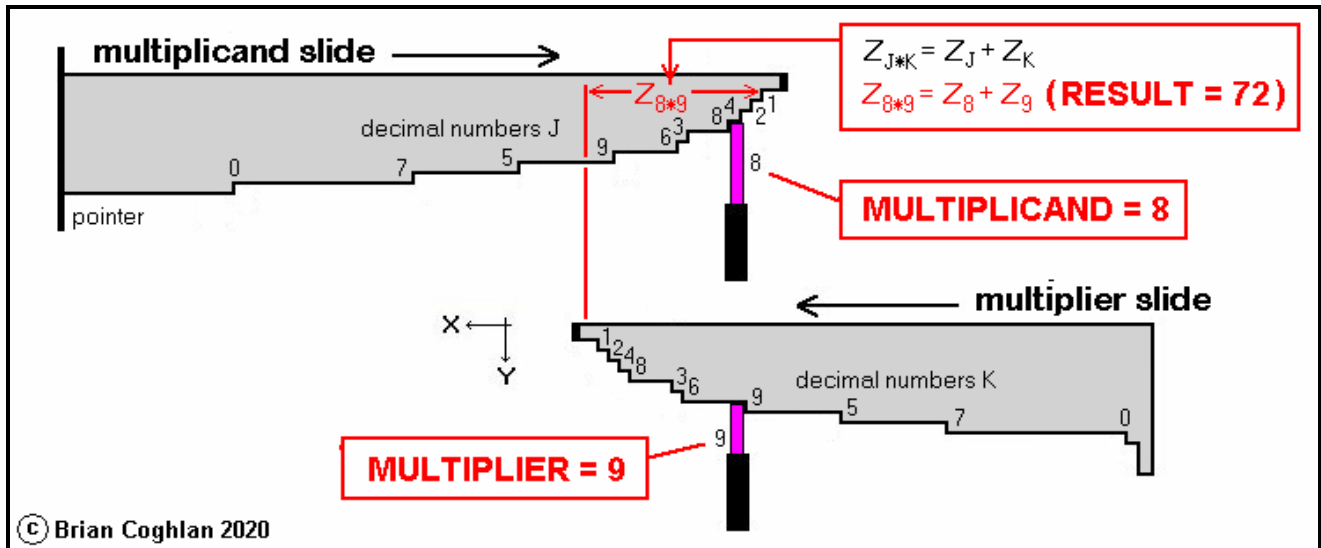


FIG. 4—Multiplication using Ludgate’s logarithmic slides for calculation of $8*9 = 72$ (Image courtesy of The John Gabriel Byrne Computer Science Collection).

Fig. 4 shows one of the set of multiplicand slides that has been moved to the right until this particular slide has been stopped by a rod whose vertical extent represents the Irish logarithm of the digit ‘8’. This is in fact the first digit of the four-digit example multiplicand (‘8132’) in Ludgate’s 1909 paper (the *Engineering* article has a six-digit multiplicand ‘813200’). Fig. 4 also shows that the (single) multiplier slide has been moved to the left until stopped by a rod representing the Irish logarithm of the digit ‘9’ (the first digit of the four-digit example multiplier ‘9247’ of both Ludgate’s 1909 paper and the *Engineering* article). However, just how the extent of the increase in overlap is transmitted to the Mill is unclear.

Ludgate’s planned machine was, like Babbage’s, to be an entirely mechanical device, but Ludgate’s design was evidently very different to Babbage’s. It is not known whether the main mechanisms were realizable with the technology of the time. It was small, about the size of a bar fridge. It had a Mill to add like Babbage’s (but presumably not influenced by him), an Index to multiply via Irish Logarithms (an entirely new idea), and compact Storage via rods and shuttles (another new idea). Sequencing and number

⁸¹ Coghlan et al, ‘Investigating the work and life of Percy Ludgate’, cf. n.18 above.

input were via a perforated paper sheet or roll in the same vein as Babbage's strung-together punched Jacquard cards, but quite different (and again in all probability not influenced by him). Both the sequencing and the storage differences are at least as significant as the arithmetic differences, even though they are not as great. It is not appropriate here to go into further technical detail, but a much fuller explanation is given in a recent paper,⁸² while our most up-to-date understanding is documented in a work-in-progress online paper.⁸³ There is no evidence that Ludgate ever made any attempt to build this machine. After Ludgate's 1909 paper, and Prof. Boys' 1909 report in *Nature*, there seems to have been very little mention of his work. For example, the 1911 edition of *Encyclopædia Britannica* does not mention his ideas.⁸⁴

No obvious motivations or influences have been discovered, despite scientific, commercial and ancestral searches. In the family domain, for example, there is only a small probability that his brother Frederick could have had much influence on Percy's Analytical Machine design during the seminal period 1903-9, as he lived in Tullamore during 1902-9.⁸⁵ Similarly, in the commercial domain, it does not appear that Ludgate's novel multiplier mechanism was influenced by the very different multiplier mechanisms on sale in the late nineteenth century or early twentieth century.⁸⁶ And scientifically, Ludgate's multiplier mechanism was totally new, with the only influences likely to be the logarithmic principles developed from the early seventeenth century onwards (again see the work-in-progress online paper).⁸⁷

IV. PERCY LUDGATE'S LATER LIFE

By 1911, Percy's brother Thomas and wife Bedelia were still in Cork, and his sister Augusta was still in Great Britain.⁸⁸ By then also Frederick, Alice and their daughter Violet had moved to 17 Carlingford Terrace (the street just behind Dargle Road), and Percy, his mother and his brother Alfred were still at 30 Dargle Road.⁸⁹ Thomas, Frederick and Alfred were listed in the census respectively as a land agent's cashier, a flour and provision agent, and as a solicitor's clerk. Percy was listed as a commercial clerk to a corn merchant, but it is not known by whom he was employed or when this employment began. It is possible it was a first step towards an accounting career.

⁸² Coghlan et al, 'Investigating the work and life of Percy Ludgate', cf. n.18 above.

⁸³ Coghlan, 'Percy Ludgate's analytical machine', cf. n.19 above.

⁸⁴ Encyclopædia Britannica, *Calculating machines* (1911). Available at: https://en.wikisource.org/wiki/1911_Encyclop%C3%A6dia_Britannica/Calculating_Machines

⁸⁵ 'Tullamore Sessions 5 July 1902', *Midland Tribune*, 5 Jul. 1902, 1; 'Tullamore Sessions 1 May 1909', *Leinster Reporter*, 1 May 1909, 3; 'King's County Assizes 2 March 1909', *Midland Tribune*, 6 Mar. 1909, 4.

⁸⁶ John Wolff, Personal communication to Brian Coghlan (21 Feb. 2017).

⁸⁷ Coghlan, 'Percy Ludgate's analytical machine', cf. n.19 above.

⁸⁸ In the 1911 Irish Census Thomas and Bedelia are listed at 173 Gurteenaspig, Bishopstown, Cork. Percy's sister Augusta was recorded in the 1911 U.K. Census as an independent woman boarding in St.Pancras, London.

⁸⁹ NAI, *1911 Census Returns*. Note: Carlingford Terrace is now part of Carlingford Road.

In 1914 his second paper, *Automatic Calculating Machines*, was published in the *Handbook of the Napier Tercentenary Celebration*, which took place in Edinburgh on 24-27 July.⁹⁰ The Celebration was a major event, which attracted an international audience and had wide coverage in the press. Ludgate's second paper focused on Babbage's Analytical Engine, but briefly mentioned his own 1909 design for his Analytical Machine, and a subsequent and intriguing difference engine design.⁹¹

Randell's 1971 paper states that 'during the 1914-18 war he [Ludgate] worked for a committee, set up by the War Office, headed by Mr. T. Condren-Flinn, senior partner of Kevans & Son' (accountants, Pl. VI),⁹² to 'control the production and sale of oats' for the cavalry, which 'involved planning and organisation on a vast scale, and Ludgate was much praised for the major role that he played'.⁹³ Kevans & Son letterhead of 1917 confirms the senior partners were Edward Kevans and Thomas Condren Flinn, both chartered accountants.⁹⁴ The Ministry of Food established the Food Control Committee for Ireland in September 1917,⁹⁵ and it established three Oat Committees in September 1918, with Kevans & Son coordinating the Midlands Oat Committee.⁹⁶ But it has not been possible to locate any actual evidence that the oats were intended for the cavalry, or that Ludgate was praised in relation to this.

Ludgate is often said to have been an accountant, but that was not the case until eight years after his 1909 paper. In 1971, Ludgate's niece stated to Randell that Percy studied accountancy at the Rathmines College of Commerce, where he was awarded a gold medal,⁹⁷ and was employed at Kevans & Son. It is not known

⁹⁰ Percy E. Ludgate, 'Automatic calculating machines', in: Ellice Martin Horsburgh (ed.), *Napier tercentenary Celebration: handbook of the exhibition (also published as Modern instruments and methods of calculation)* (London 1914), 124-7.

⁹¹ Brian Coghlan, 'Speculations on Percy Ludgate's difference engine'. Available at cf. n.14 above.

⁹² Kevans & Son occupied Caledonian Chambers, 31 Dame Street, which was designed for the Caledonian Insurance Company in Ruskin-style by the architect James Edward Rogers, see: <http://www.patrickcomerford.com/2016/12/a-unique-building-on-dame-street-dublin.html>. Kevans & Son was ultimately subsumed into Price Waterhouse Cooper, now known as PwC.

⁹³ The likely source of this information was 'Mr. E. Dunne ... who joined the firm of Kevans & Son in 1921' (from Randell's 1971 paper, cf. n.8 above).

⁹⁴ NAI, NAI/PLIC/1 PLIC-1-430, 8 July 1916; PLIC-1-6323, 8 Feb. 1917. Edward Kevans was a founder member, and President (1901-20), of the Irish branch of the Society of Accountants & Auditors (S.A.A., renamed Society of Incorporated Accountants & Auditors, S.I.A.A., in 1908). Thomas Condren Flinn was Edward Kevan's clerk, becoming a chartered accountant in 1906, and Kevans' partner and successor.

⁹⁵ The Food Control Committee for Ireland (Secretary T. J. Kinnear) was established for 'Defence of the Realm' by the Ministry of Food on 3 Sep. 1917. See: TNA, 'Oats Control Committee', MUN 4/6489, Sept. 1915; TNA, 'War Committee: Oats', CAB-42-14-2, 18 May 1916; TNA, 'War Cabinet: Irish Oats', CAB-24-25-76, 19 Aug. 1917; 'New food regulations: Irish committee appointed', *Irish Times*, 3 Sep. 1917, 3.

⁹⁶ The Food Control Committee for Ireland established Northern, Southern and Midlands Oat Committees in 1918. Kevans & Son coordinated the Midlands Oat Committee. See: 'Notice to oats merchants', *Irish Independent*, 25 Sep. 1918, 4; 'Notice to grain merchants', *Nenagh Guardian*, 26 Oct. 1918, 2.

⁹⁷ The college was founded as Rathmines Municipal Technical Institute in 1901, renamed later, and subsumed into Dublin Institute of Technology in 1992 by the *Dublin Institute of Technology Act* (Government of Ireland, 1992). The college records have not been located.

when the latter began, but certainly in 1917 (aged 34) he was awarded honours in Accountancy,⁹⁸ after being examined by the Corporation of Accountants.⁹⁹ This body held Preliminary, Intermediate and Final examinations in Dublin in June and November, and allowed exemptions from the Preliminary examination.¹⁰⁰ Ludgate's name does appear amongst the published 1916 Intermediate,¹⁰¹ and the 1917 Final examination results,¹⁰² but Preliminary exam results were not published for previous years. Examination by this body provided the least-expensive option for Ludgate to become an accountant in that era,¹⁰³ as it did not require putative accountants to be apprenticed,¹⁰⁴ nor to attend university (the subject was not taught in any Dublin university until he was embarked on his studies).¹⁰⁵ Conceivably these studies and his subsequent Oat Committee duties and work at Kevans & Son cut short his nocturnal work on his machines.

World War I ended in Nov. 1918, when Ludgate was 35 years old, overlapped by the Spanish Flu epidemic which lasted from May 1918 to Mar. 1919.¹⁰⁶ The subsequent Irish War of Independence (1919-21) led to partition of Ireland in May 1921, and the Anglo-Irish Treaty in Dec. 1921. In that month Ludgate's brother Frederick died of tuberculosis (*phthisis*) at his family's then home at 1 Tolka Villas, Richmond Road, Drumcondra.¹⁰⁷

⁹⁸ Corporation of Accountants, 'Corporate accountants, results of the June examination', *Freeman's Journal*, 15 Sep. 1917, 2.

⁹⁹ The Corporation of Accountants was originally formed in Scotland in 1891, only in 1939 becoming part of the Association of Certified and Corporate Accountants (ACCA), a worldwide body that certifies accountants, then was granted a royal charter in 1974 and changed its name to the Association of Chartered Certified Accountants (again ACCA).

¹⁰⁰ Three examinations had to be passed, Preliminary, Intermediate and Final. Fees for the exams were 10s.6d, £1.1s.0d and £1.11s.6d respectively. The Preliminary Examination was for the following subjects: Writing from dictation, English grammar and composition, Arithmetic, Geography, English history, Elementary algebra, Euclid Book 1, Elementary Latin, French or German. Candidates possessing the necessary fundamental knowledge could be exempted from the necessity of passing the Preliminary Examination.

¹⁰¹ Corporation of Accountants, 'Corporate Accounts Exams', *Irish Independent*, 2 Sep. 1916, 4; 'Corporate Accountants Examinations', *Freeman's Journal*, 2 Sep. 1916, 3.

¹⁰² Corporation of Accountants, 'results of the June examination', cf. n.98 above.

¹⁰³ Peter Clarke, 'The historical evolution of accounting practice in Ireland', *Irish Accounting Review* 12 (Special Issue, 2006), 1-23.

¹⁰⁴ Tony Farmar, *The versatile profession: a history of Accountancy in Ireland since 1850* (Chartered Accountants Ireland, 2013). Apprenticed accountants are now referred to as 'articled'. The Institute of Chartered Accountants in Ireland (ICAI), now called Chartered Accountants Ireland, operated under a royal charter from 1888, with exacting financial and examination burdens, including the requirement to be apprenticed.

¹⁰⁵ A Commerce & Accountancy chair was created at University College Galway in 1914, and a Commerce faculty at University College Dublin in 1916.

¹⁰⁶ Ida Milne, *Stacking the coffins, influenza, war and revolution in Ireland 1918-1919* (Manchester, 2020).

¹⁰⁷ Death certificate for Frederick Ludgate (Dublin, 2 Dec. 1921). Available at: <http://www.irishgenealogy.ie/>



PL. VI—31 Dame Street, Dublin (with flag), where Percy Ludgate worked as an accountant (Image courtesy of The John Gabriel Byrne Computer Science Collection).

Ludgate remained with Kevans & Son as an accountant until his death in Oct. 1922. In Randell's 1971 paper there are two attestations to Ludgate's character. Firstly, according to an accountancy colleague he 'possessed characteristics one usually associates with genius, ... he was so regarded by his colleagues on the staff ... humble, courteous, patient and popular'. Secondly, according to his niece Violet, daughter of Frederick and Alice, 'Percy ... took long solitary walks'; he was a '... gentle, modest simple man'; she '... never heard him make a condemning remark about anyone', she thought him '... a really good man, highly thought of by anyone who knew him', and he '... always appeared to be thinking deeply'. The only known photograph of him, provided by Violet to Randell, is shown in Pl. VII(a), probably taken in the last five years of his life. He never married.

Randell's 1971 paper stated that in October 1922 Percy developed pneumonia after a holiday in Lucerne and was nursed by Frederick's wife Alice. On 16 Oct. 1922, he died aged 39 at 30 Dargle Road, quickly followed on 22 Oct. 1922 by Alice aged 47 at the Adelaide Hospital.¹⁰⁸ In the U.K. and Ireland, life expectancy was 57 years in 1922,¹⁰⁹ and his family died at an average age of 58 years, so Percy died younger than expected. That Alice died six days later suggests a highly infectious illness. His death certificate states the cause of death as catarrhal pneumonia,¹¹⁰ which mostly accompanies diseases like influenza.¹¹¹ Both Percy and Alice were buried in the Ludgate family grave in Mount Jerome Cemetery that Percy had purchased for Frederick's burial.¹¹²



This is the last Will and Testament of me, Percy Edwin Ludgate, of No 30 Dargle Road, in the City of Dublin And.
26th day of June One thousand nine hundred and seventeen.

PL. VII—(a) Percy Ludgate (Image courtesy Brian Randell), (b) Excerpts of Percy Ludgate's handwriting from his will (Images courtesy of National Archives of Ireland).

¹⁰⁸ Death certificates: Percy Edwin Ludgate (Dublin, 16 Oct. 1922); Alice Emily Ludgate (Dublin, 22 Oct. 1922). Available at: <http://www.irishgenealogy.ie/>

¹⁰⁹ Max Roser, *Life expectancy*. Available at: <https://ourworldindata.org/life-expectancy/>

¹¹⁰ Now called bronchopneumonia.

¹¹¹ Guthrie McConnell, *A manual of Pathology* (Philadelphia, 1915).

¹¹² *Mount Jerome Cemetery*, Harold's Cross, Dublin. Available at: <http://www.mountjerome.ie/>

Ludgate's original handwritten will of 26 June 1917 survives.¹¹³ It is the only known example of his handwriting, extracts of which are shown in Pl. VII(b). He bequeathed his estate to his mother Mary (who was then aged 82), or, if she predeceased him, to his niece Violet, and made his brother Alfred his executor with £50 in lieu. Alfred administered probate, declaring relatively modest assets that include War Loans and War Savings with interest, bonds in the UK, Post Office and bank accounts plus cash, but just an estimated £10 of personal effects, and no real property, for a total value of £885.7s.4d, including London assets of £192. The debts included medical expenses for a local Drumcondra pharmacy, and a local doctor, Thomas Codd,¹¹⁴ and to another doctor in Merrion Square, Michael Cox,¹¹⁵ and funeral expenses plus cemetery fees. Also included is rent of £5.18s.8d to a Miss Lennon, 78 Queen Street.¹¹⁶ After estate duty including interest was paid, the residue was £812.12s.10d. Probate was proven in Dublin on 23 Jan. 1923 and in London on 12 Feb. 1923.

V. PERCY LUDGATE'S FINAL RESTING PLACE

In 1911 Percy Ludgate's father, Michael Edward Ludgate was living in Omagh, Co. Tyrone, as Edward Ludgate, single and an army pensioner.¹¹⁷ He applied in 1919 for one of the new state pensions. He died three months after Percy in 1923 in the Union Infirmary, Belfast, and was buried in the Belfast City Cemetery.¹¹⁸ The burial was arranged and paid for by the Infirmary in the City Cemetery, which suggests he had a pauper's grave.¹¹⁹

After Percy's death, it appears that his mother Mary, brother Alfred and niece Violet remained at 30 Dargle Road until 1935. His mother died aged 96 in 1936. When Alfred administered Percy's probate he declared himself an accountant, but no evidence has been found confirming that he was a qualified

¹¹³ NAI, *NAI/CS/PO/TR Will of Percy Edwin Ludgate*, 26 June 1917.

¹¹⁴ Dr. Thomas Paul Codd, of 78 Lr. Drumcondra Road, died aged 62 years on 12 Nov 1922 ('self-administered opium poisoning').

¹¹⁵ Dr. Michael Francis Cox (1852-1926), 26 Merrion Square North, was one of Dublin's leading doctors, a physician at St Vincent's Hospital, consulting physician to several Dublin hospitals, including the National Hospital for Consumption, with a large private practice. He was a member of the RIA, elected President of the Royal College of Physicians in 1922, but fell ill in 1923.

¹¹⁶ Neither the 1901 or 1911 Census lists Lennons at that property (corner of 78 Queen St and 1 Benburb St). The 1911 Census lists a Lennon family with four daughters aged 12-22 years at 66.3 Queen St, and another Lennon family with one daughter aged 5 years at 44.2 Benburb St, neither close nearby. The 1910 *Thom's Directory* lists a Mary Lennon at 73 Queen St, but in the 1911 Census that building is listed as 'Storage'.

¹¹⁷ TNA, *1911 UK Census Returns*.

¹¹⁸ For details of births, marriages and deaths referred to in Section V, see: 'Percy E. Ludgate prize in Computer Science', cf. n.22 above, especially sections: *Ancestors of Percy Edwin Ludgate*; *Ancestors of Barbara Hopkins*; *Ancestors of Eileen Mary Ludgate*.

¹¹⁹ Belfast City Cemetery Application for Internment 58375.

accountant.¹²⁰ After his mother's death Alfred lived in the environs of the North Circular Road. Thomas & Bedelia, whose only daughter died in infancy, moved from Cork to England and settled at Blue Hazel Cottage, Chailey, in the environs of Newhaven and Peacehaven, Sussex.¹²¹ Bedelia died in Newhaven in 1934 and Thomas died in Lewes in 1951. Alfred died in 1953 in the Royal Victoria Eye & Ear Hospital where his niece Violet was employed as an Almoner's clerk, but his death was registered by the hospital, not by Violet. Randell's 1971 paper states that Percy's drawings or manuscript were not found amongst Alfred's effects. Percy's sister Augusta was recorded in the 1939 U.K. Register as institutionalized in Leavesden Mental Hospital, Watford U.K.,¹²² where she died in 1954.

Thus by 1954 Percy, his parents and siblings had all died. Those who died in Dublin were buried in the same grave in Mount Jerome Cemetery.¹²³ His only niece Violet, daughter of Frederick and Alice, lived at 39 Wellington Road, Dublin until 1987, when she died in St. Vincent's Hospital in Elm Park. Her probate shows she donated her body to Trinity College Dublin for medical research, finally to be interred at the Cruagh Cemetery.¹²⁴ Only one person has been found thus far who remembers Violet,¹²⁵ and Randell communicated with Violet only by letter. Consequently, until recently it was thought that, since Ludgate's parents and siblings had died by 1954, and his niece Violet had died in 1987, that there were no living descendants of his parents. Then in 2018 it was discovered that Violet had given birth to a daughter Barbara in 1935.¹²⁶ She was privately adopted and, renamed Anita, brought up in Jamaica. She married and moved to America, where she and her husband raised a family, see Fig. 5.

¹²⁰ Alfred Ludgate declared he was an accountant employed at George Drevar Fottrell & Sons (solicitors), 46 Fleet St, Dublin. There is a letter from his employer attached to probate, but no evidence that he was an accountant. *Thom's Directory* listed accountants, but never listed Alfred Ludgate, whilst continuing to list Percy Ludgate until 1929.

¹²¹ TNA, 1939 UK Register, *Thomas Ludgate, Chailey Road, Sussex* (1939). They are not in the 1914-15 Worthing Directory, or the 1915, 1922 or 1927 Kelly's Sussex Directory, or the 1934-6 Lewes, Seaford, Newhaven Blue Book.

¹²² TNA, 1939 UK Register, *Leavesden Mental Hospital, Watford* (1939).

¹²³ *Mount Jerome Cemetery*, cf. n.112.

¹²⁴ NAI, 2008/1/6769 *Ludgate, Violet: will and associated papers*, 1 Oct. 1985.

¹²⁵ Brian Coghlan, Personal communications (Jan. 2019).

¹²⁶ Brian Coghlan, Personal communications with Trish Gonzalez (7 Dec. 2018), prompted by an old entry (5 Aug. 2013) on a genealogy message board.

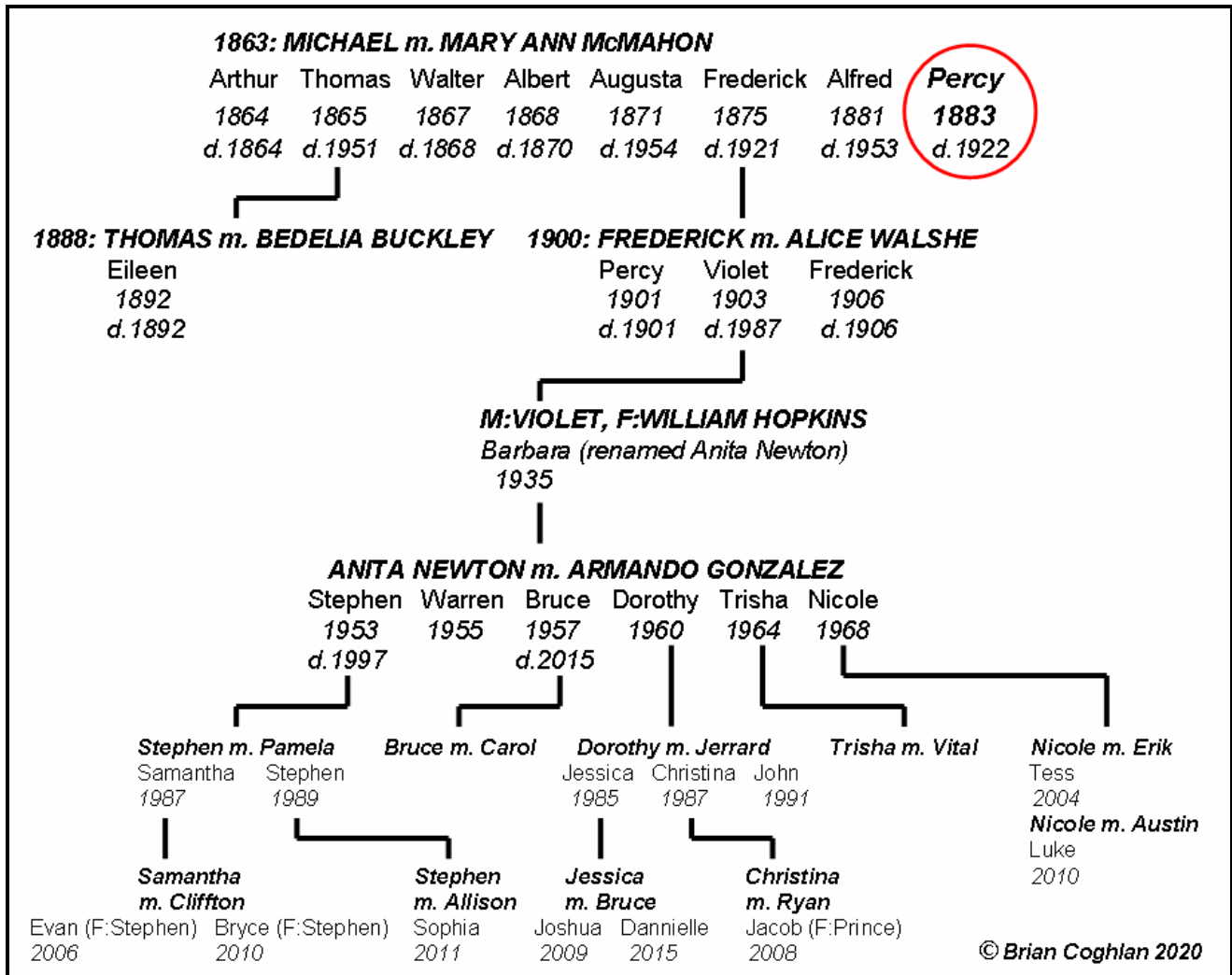


FIG. 5—Descendants of Frederick Ludgate and Alice Ludgate née Walshe (Image courtesy of The John Gabriel Byrne Computer Science Collection and the Gonzalez family).

Percy's home at 30 Dargle Road (where he did his work on his Analytical Machine), which was occupied by the Ludgates from 1899-1935, exists in good condition. By contrast the Ludgate grave, occupied by Frederick, Percy, Alice, Mary and Alfred,¹²⁷ who made no will, long lay unmarked and in poor condition. Since the grave could only be marked with permission from the owner, or by close descendants, the identification of Anita Newton has allowed this to be addressed, and her children, who are direct descendants of three occupants of the Ludgate grave, were in 2019 allowed to erect a grave marker (Pl. VIII).

¹²⁷ National Archives or Ireland, *NAI/CS/PO/TR Will of Percy Edwin Ludgate*. cf. n.113 above, and *Mount Jerome Cemetery*, cf. n.112.



PL. VIII—Ludgate grave, before and after Sept. 2019 (Images courtesy of The John Gabriel Byrne Computer Science Collection).

VI. CONCLUDING SUMMARY

Percy Ludgate, who was born, lived, worked and died in Ireland, published his Analytical Machine paper in the *Scientific Proceedings of the Royal Dublin Society* in 1909. Prior to the present paper, he presented two sets of unknowns, one in regard to his life and the other regarding his machine. Firstly, he died young and single, and by 1987 there were no known descendants of his parents or extended family, so family and personal details were scarce. Secondly, his 1909 paper explained key principles of his machine, but it was not very forthcoming otherwise, as none of the many drawings of the machine and its parts that Ludgate stated in 1909 and 1914 he had prepared had been found. It is possible that World War I interrupted the dissemination of his work. His ideas seem to have been forgotten by the time of Baxendall's 1926 *Science Museum catalogue of Calculating Machines and Instruments*,¹²⁸ in which Ludgate's mention as the designer of a difference engine (rather than of his Analytical Machine, which went unmentioned) stimulated Randell's 1971 investigation.

The new material in the present paper has all been found since 2016, the majority since January 2017. There have been two particularly significant discoveries, firstly at Christmas 2018 of the existence of his niece Violet Ludgate's daughter and descendants, secondly at Christmas 2019 of the article and especially

the diagram in an August 1909 issue of the little-known journal *Engineering*.

The first discovery occurred as a result of the extensive genealogical investigation that has permitted the identification of Percy Ludgate's ancestors back to the 1700s. During these activities it was found that another genealogist was also researching the Ludgate family. This led to the discovery of an unsuspected set of Violet Ludgate's descendants in America (one of whom joined the investigation), who were legally entitled to place a memorial on Percy Ludgate's unmarked grave. His life still presents many mysteries about his education, health, Civil Service and subsequent career. There remains a hope of finding further descendants of the later generations that were contemporary with Percy Ludgate, and hence the possibility of obtaining through them additional information. But the existing results are a clear testament, firstly to the potential of the Internet and pervasive computing for collaborative historical investigations, secondly, to the power of modern genealogy not only to create extended family trees but also to discover records that unveil the life of a family, and thirdly to the immense value of the continuing digitization of historical documents and records.

The second discovery was a direct outcome of the investigation's outreach activities, in co-operation with the Ludgate Hub. Prompted by this, Ralf Buelow, of Heinz Nixdorf MuseumForum, found a brief account of the kernel of Ludgate's design, published just a few months after his 1909 paper. Astonishingly this account, like the more comprehensive account in the journal *Engineering* upon which it was based, contained an explanatory diagram that must have been provided by Percy Ludgate himself. This single diagram is of significant value in obtaining a more complete understanding of Ludgate's highly innovative 'Irish Logarithms' multiplication mechanism. His machine still presents many mysteries, not least his inspiration for and motivation in pursuing the design of his machine. He designed a potentially disruptive mechanical technology; his storage scheme was extremely compact; his Index would have dramatically reduced average multiplication times relative to repeated addition; these and his approach to division were novel. The latter is now common, as is multiply-accumulation (MAC), and grouping of an operation with its operands; these aspects of his design may yet have future application to miniaturized mechanical machines. The new details deduced by this research are a clear testament to the value and ability of even just a single drawing to illuminate hidden facts about a machine, hence the discovery of any further diagrams would be likely to have a significant impact.

¹²⁸ David Baxandall, *Calculating machines and instruments: catalogue of the collection in the Science Museum* (London,

The investigation has amassed a very considerable archive,¹²⁹ which is, as far as is permitted, available online within the John Gabriel Byrne Computer Science Collection. It is hoped that the present paper, and the associated archive, will prompt and encourage further research, especially in Ireland, into all aspects of Percy Ludgate's life and work.

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1926).

¹²⁹ All the biographical material and genealogical evidence is aggregated in: 'Percy E. Ludgate prize in Computer Science', cf. n.22 above. All the technical and other material is available at the Ludgate folder, cf. n.14 above.