

David Edward Hughes: Concertinist and Inventor¹

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On a late spring evening in Charleston, South Carolina, in 1845, a small family band comprised of three children appeared in front of a large audience of well-to-do planters and town folk in that city's Hibernian Hall. Each attendee had paid fifty cents to see and hear the little group, which performed four times over the course of a week in a highly-touted booking. The youngest member of the band was a girl of only seven, who sang operatic airs and played the harp 'with great originality of genius'.² A slightly older lad played the violin in a manner 'creditable to old and experienced masters, not excepting Paganini himself'. Of the eldest boy, who was fourteen, it was said that 'his flying fingers swept the lyre'. This boy also performed on the English concertina, about which the reviewer could only muster the phrase 'a most pleasing instrument'. For the past five years, David Edward, the fourteen-year-old, and the 'Hughes Family' had been playing in similar venues across the United States, Canada, England, and the West Indies.

These Charleston concerts, which took place on the 6th, 8th, 12th, and 15th of May 1845, as well another by that family that took place at the Saloon of the Washington Museum on February 12, 1841 and still others from 1840-1845 in Washington, New York and Baltimore³, are landmarks of sorts in the history of the concertina: they mark some of the earliest documented appearances of the English (or any other kind of) concertina in American music circles.⁴ The band's concertinist was David Edward Hughes (1831-1900), a musical child prodigy and mechanical genius whose later inventions did much to make today's communication, broadcast, and recording industries possible, and who was one of the most decorated and renowned scientists of his day. And of particular interest to concertinists is this: his scientific life and inventions, which followed his youthful days as a musician, display amazingly close similarities to those of Sir Charles Wheatstone (1802-1875), the inventor of the English concertina. Both scientists came from family backgrounds rich in music, both tinkered at length with schemes for mechanically made, transmitted, or recorded music early in their technical careers, and both went on to make major discoveries and quite similar inventions in the then-new field of long-distance electrical communication. While Wheatstone's life has been comprehensively described by Brian Bowers,⁵ this brief contribution will explore Hughes's life, with emphasis on its parallels with that of Wheatstone.



Figure 1. Engraving of David Edward Hughes, age ten (c. 1841); one of the earliest known images of a concertinist . Reproduced courtesy Ivor Hughes.

The Young Concertinist

David Edward Hughes was born to musically talented Welsh parents in London on 16 May 1831.⁶ His father, David Hughes (born c. 1803), was the son of a Welsh bootmaker; about his mother, Catherine (born c. 1798), little is known. The couple had four children: Joseph Tudor (born c. 1827), David Edward, John Arthur (c. 1835), and Margaret (c. 1838), and tours of English concert halls began when the eldest son, Joseph Tudor, was only five.

Just when the family added a concertina to its act is uncertain, but we might note that there is an entry for a 'Captⁿ Hughes' in a Wheatstone sales ledger on 22 June 1836.⁷ Needless to say, considering the Captain a member of our Hughes family would go a long way in explaining how David Edward came to the instrument (see below).

In 1840, the family emigrated to America, arriving in New York City on the ship *Catharine* on 8 October 1840.⁸ Their entry papers list David, Sr., as a 'teacher of music', while the three boys are listed as 'musicians'. The family began to perform on tour later that year, their performances even including one at the White House. Then, after a hiatus of some months following the tragic drowning of Joseph Tudor in the Hudson River in 1841, they resumed performing, and toured in Canada and the West Indies before setting down on a farm in Virginia.

It is also from around this time that we have an engraving of the ten-year-old David Edward (Fig. 1), possibly the oldest surviving image of any musician playing a concertina. It shows a fair-haired David, family concertina in hand, dressed in the style of the day, and with two medals proudly displayed around his neck. Charming as it is, the drawing is naively executed: David's feet are drawn overly (if fashionably) narrow, and the concertina is so crudely drawn that, while the thumb straps leave no doubt that we're dealing with an English, an unknowing observer would find it hard to say just how many sides it has.

Only a few period newspaper accounts of Hughes family concerts have survived. Five year old Joseph played the harp at the Strand Theatre in London in 1832.⁹ A few years later another London concert featured two brothers, in which a violin and harp were played.¹⁰ A third set of accounts describe the above-mentioned concerts in Charleston and other cities on the eastern seaboard of the United States in the period 1840-1845 (see Figures 2 and 5). The Charleston concert had been carefully planned, with several advertisements appearing in the city's press in the days leading up to and during the performances. One of the advertisements—that in *The Southern Patriot* on 7 May—contains an image of the 'Hughes Family' that seemingly includes the entire family of six (Fig. 2). The teenage David stands in the middle holding his concertina, flanked on his right by little Margaret with her harp. John Arthur, standing on a platform, holds his violin at the far right of the image, which also accounts for three other members of the family, though they seem not to have

participated at the Charleston concerts: the parents, David, Sr., and Catherine, both standing by harps, and perhaps, at the far left, a posthumous portrait of the deceased Joseph Tudor. The advert is also valuable for its information about the trio's repertory: 'the choicest selections from the most favorite *Operas* and *National Melodies*, together with ORIGINAL AIRS and VARIATIONS, of their own composition.'¹¹

The Hughes' Family



RESPECTFULLY announce to the friends of MUSIC in Charleston, that they will give their second CONCERT To-Morrow Evening, at Hibernian Hall. PROFES-OR STRONG will perform on the PIANO FORTE.

The CONCERTS of the MASTERS HUGHES' have created the greatest surprise and astonishment in the Musical world, and attracted the most distinguished audiences in all the principal cities of Great Britain, the Canadas, the United States and the West Indies. Their performances on the HARP, VIOLIN and CONCERTINA, comprise the choicest selections from the most favorite *Operas* and *National Melodies*, together with ORIGINAL AIRS and VARIATIONS, of their own composition.

Doors open at half past 7 o'clock; performance to commence at 8 o'clock. Admission 50 cents, children half price.

May 7

Figure 2. Advertisement for one of the Charleston, South Carolina concerts by the Hughes Family in *The Southern Patriot*, 7 May 1845. David Edward Hughes is in the center of the group, holding an English concertina.

David's musical skills were such that he was noticed by a German-American pianist named Herr Hast, who obtained for the nineteen-year-old David a professorship of music at St. Joseph's College in Bardstown, Kentucky, a Jesuit school in a town just one step removed from the frontier.¹² While there he wrote numerous compositions, one of which, titled *Lizzie Polka*, was published at Cleveland in 1852.¹³ At the same time, he developed such a proclivity for mechanical and physical sciences that he was also appointed to a chair in natural philosophy. As we shall see, Hughes came to the sciences through his interest in the physics and mechanics of music and sound, just as Charles Wheatstone had some thirty years earlier. Yet biographers

of Hughes seem unaware of Hughes's prior history with the Wheatstone concertina. In fact, biographers of Hughes seem unaware of the amazing parallels between the work of the two men.

The Mature Inventor

While teaching at St. Joseph's, Hughes began to investigate the possibility of writing music in an automated fashion on paper by playing the notes on a keyboard; in effect, he sought a tool not unlike today's midi devices. He devised a machine to do this that used pulses of electrical current sent by a piano-like keyboard to typeface characters set in a rotating wheel which printed onto a spool of paper tape. Thus at the tender age of twenty-three, Hughes had inadvertently created the telegraph printer (Fig. 3), the direct ancestor of the telex machine, teleprinter, and, in many respects, the computer keyboard.



Figure 3. Fig. 3. Hughes's first telegraph printer, patented in 1855.

This machine allowed for the first time the commercial transmission and printed reception of Roman letters rather than code. Realizing the potential of his creation, he resigned his position at St. Joseph's, and spent the next two years perfecting it. As his obituary in *The Electrician* puts it, the instrument

. . . was speedily taken up in the United States as a formidable competitor to the Morse system, monopolised by the American Telegraph Co. A patent for this instrument was taken out in the United States in 1855, and in less than two years a number of small telegraph companies, including the Western Union—which was at that time in its early stages of development—had united to form one large corporation, the present Western Union Telegraph Co., to carry on the business of telegraphy on the Hughes system.

In that same year Prof. Hughes returned to England for the purpose of introducing the instrument to the then existing Electric Telegraph Co., which controlled the telegraphic business in this country. Failing, however, in this endeavour, Prof. Hughes was compelled to carry his invention across the Channel to France, where it met with a much more enthusiastic reception at the hands of the French Government, who agreed to give the instrument a year of practical trial on the French land lines, and if found satisfactory it was to be finally adopted. Aided by his experience already acquired in America, Prof. Hughes was able to make the experimental trial a thorough and complete success. The instrument was adopted in France, and indeed throughout Europe. . . .¹⁴

The only major industrialized country in which the Hughes system of telegraphy was not soon adopted was England, where the Wheatstone and Cooke system had been placed into commercial use soon after its invention in 1837; clearly that system was so entrenched that this new competitor was ignored. Yet even in England Hughes eventually enjoyed success, and his system was finally taken up there 1863.¹⁵ In an interesting parallel, Wheatstone also appears to have considered and devised a telegraphic printer as early as 1841, but never brought it into commercial use, thinking it too slow and too expensive.¹⁶ There is no evidence that Hughes was aware of Wheatstone's unpublished work, and his (Hughes's) design shows no similarities in construction.

Hughes spent much of the two decades following his invention of the telegraphic printer on the Continent, installing his system in one country after another. Following that, he settled in London in 1877, taking up residence at 108 Great Portland Street, where—in another parallel with Wheatstone's career—he developed the carbon microphone in 1878. It had been fifty-one years since Wheatstone had experimented with the transmission of sound waves along metal rods, speculating that such a non-electrical method might take music and messages from London to Edinburgh. At the same time, Wheatstone constructed a similarly non-electrical device consisting of two rods that amplified faint noises when brought close to the listener's ears. He coined the term 'microphone' for the device, though it had little more than its useful name in common with the electrical microphones that were to come a half century later.¹⁷ In 1876, Alexander Graham Bell used a primitive electrical microphone invented by Emile Berliner in his first telephones. That microphone, however, was unsatisfactory, and severely limited the practical utility of the telephone. What Hughes discovered was that a loose contact in an electrical circuit between battery and transmitter produced a much better transmitted sound, and with this discovery he built the first carbon microphone, using such crude materials as toy boxes, sealing wax, and wires in the drawing room of his home. As the obituary in *The Electrician* states, 'it was not until Hughes. . . that practical telephony became a possibility'.¹⁸ The carbon microphone is the direct prototype of most microphones in use today, and was a

critical element in the development not only of telephony, but of the broadcasting and recording industries yet to come.

We may measure the character of the man by what he did with this latest invention. By now Hughes was already famous and well-to-do as a result of his telegraph printer. He therefore decided to simply *give* his new invention, the carbon microphone, to the world by refusing to take out a patent. He reported his invention to the Royal Society in London on 8 May, and made it and its details available to the general public on 9 June. This streak of scientific idealism is a characteristic that Hughes had in common with Wheatstone, who forty years earlier had planned to simply publish his groundbreaking findings on the telegraph to 'allow any person to carry them into practical effect'. Before Wheatstone could carry out his intention, however, his commercially-minded partner-to-be, William Cooke, convinced him to take out a patent and establish a commercial venture.¹⁹

Another of Hughes's important inventions came in 1879, when he developed the induction balance, which saw early use in metal detectors. Originally, it consisted of an *arrangement of coils whereby the currents inducted by a primary circuit in the secondary [circuit] are opposed to each other until they balance, so that a telephone connected in the secondary circuit is quite silent. Any disturbance of this delicate balance, however, say by the movement of a coil or a metallic body in the neighborhood of the apparatus, will be at once reported by the induction currents in the telephone*'.²⁰

The very sensitive device was soon used in all sorts of metal detection, such as finding submerged torpedoes or in assessing the purity of metal in coins; it is still used in modern metal detectors such as those in airport security. The device is also extensively used in today's medical imaging through EMI (electro-magnetic inductance), a field that began soon after Hughes invented the balance. In 1881, President James Garfield was shot by an assassin, and lingered for eleven weeks with a bullet lodged hidden in his back; he was soon to die from infection caused by the hordes of physicians who tried to find the bullet. Alexander Graham Bell, the inventor and a friend of Hughes, had heard of the new invention and decided to try it in the race to find the bullet. Although Hughes's balance was proven fully capable of finding the bullet through some practical tests that were devised in the hours before it was used on Garfield, the device failed on this critical first application because unbeknownst to Bell, the ailing Garfield was placed on a newly-invented coil spring mattress, and the metal bedsprings interfered with Hughes's device.²¹

Finally, we must mention Hughes's work in discovering long-distance wireless transmission via radio waves. This came about in 1879, as he experimented with his home-built telephone, built to the specifications of his friend Bell's invention of 1876. When using his new induction

balance across the room, he heard clicks in the telephone and correctly inferred they were produced by waves of electromagnetic energy as opposed to simple induction. To test this, he went from room to room in his house and then went outside into the London streets, listening to his battery-powered telephone receiver in what some term, in somewhat tongue-in-cheek fashion, 'the world's first mobile phone call'.²² By way of these home experiments, Hughes was transmitting and receiving radio waves fully sixteen years before Guglielmo Marconi demonstrated radio transmission to the world. Unfortunately, Hughes did not publish his work. Rather, as R.W. Simons (1996) writes, Hughes

*. . . showed this work to William Spottiswood (the President of the Royal Society), to Prof. Huxley, and to Sir George Gabriel Stokes, demonstrating transmission and reception from 60 yards (55m) to over 500 yards (460m) and noting the variation in signal strength with range. Stokes said that all the results could be explained by known electromagnetic effects and he therefore could not accept the suggestion that electric waves existed. Hughes was so discouraged at not being able to convince them that he refused to write up his work in a paper until he had better proof. In fact he did no further work and the record of his discouragement only came to light in a letter to J.J. Fahie in 1899.*²³



Figure 4. David Edward Hughes, c. 1890.

Much to his credit, Hughes never pushed his claim as the discoverer of radio waves, recognizing that the glory belonged to those who published their findings (Hertz

demonstrated the existence of electrical waves in 1887, and Marconi demonstrated wireless telegraphy in 1896). Late in life, however, when asked to document those early experiments for posterity, Hughes wrote an account for the London journal *The Electrician*. And in that journal's obituary for Hughes, we read that that account 'abundantly proved' that he had been 'the first to transmit actual signals over a considerable distance by means of electrically-generated ether waves; which is, in fact, the basis and essence of wireless telegraphy on the Marconi system'.²⁴ In 1922, Hughes' forgotten home-built wireless apparatus was unearthed in a London tenement, and was placed on display in a South Kensington museum.²⁵ Both Wheatstone, with his never-released telegraphic printer, and Hughes were graced with inventions of great import that never came to fruition.

Hughes was one of the most honored scientists of his day. A first honor came from France, where he was named a Chevalier of the Legion of Honor by Napoleon III in 1860. In 1867 the Paris Exhibition awarded him one of ten gold medals intended to reward the very highest achievements in science, and similar honors came from the nobility or leaders of each European country where the Hughes telegraph system was installed.²⁶ Honors in England were slower in coming, likely because of the unique position that the Wheatstone-Cooke telegraph system occupied there. Nonetheless, Hughes eventually received the Fellowship of the Royal Society in 1880 and, for his work on the microphone and induction balance, the Royal Society's Gold Medal in 1885. One year later, he was elected president of the Institution of Electrical Engineers, and in 1898, the Society of Arts conferred on him The Albert Gold Medal, a lifetime achievement-style award for all of 'his numerous inventions, especially the printing telegraph and the microphone'.²⁷

Hughes was married twice. His first wife, London-born Maria M., about whom little is known, is listed with him in the London census of 1871. Later in the 1870s, he married the New Hampshire-born artist Anna Chadbourne (1826–1919); he had no children with either wife. Hughes was known to be 'simple in tastes' and 'a most genial companion'.²⁸ When he died in 1900, a colleague reported that 'it can truly be recorded that David Hughes lived without making a single enemy, and died mourned by all whose good fortune it has been to come within the cheery circle of his friendship'.²⁹ He left most of his considerable fortune to four London hospitals, with lesser amounts bequeathed to his wife, his sister Margaret, and several technical societies.

Hughes and Wheatstone

The parallels between the careers of Sir Charles Wheatstone and David Edward Hughes are many, even surprising. Both men were among the foremost inventors of their respective generations, and both came to the physical and electrical sciences from musical backgrounds.

Wheatstone's family ran a music instrument shop and manufactured wind instruments, while everyone in Hughes's immediate family was a musician, with David Edward himself playing Wheatstone's greatest musical legacy: the English concertina. Perhaps inspired by this mechanical instrument, Hughes turned to the physical sciences and to acoustics. Here they both made lasting contributions to telegraphy, Wheatstone, by virtually inventing the field itself (concurrently with the Samuel Morse in the United States), and Hughes by furthering its rapid growth as a practical industry with his telegraph printer. Finally, both men were captivated by the idea of long-distance transmission of sound, with Hughes bringing Wheatstone's early concept of amplification and transmission of music to final fruition with the invention of the carbon microphone. Although it seems inconceivable that Hughes and Wheatstone never met, no record of such a meeting has come to light

A final thought: the next time you listen to the radio or a CD, record a tune on your iPod, type some notes on your PC, or pass successfully through airport security, raise a glass both to the concertinist of that little family band of musicians who performed across the eastern United States in the early 1840's and to the role that Wheatstone's English concertina may have played in stimulating that teenage performer's mechanical and scientific muse.

NIBLO'S SALOON.

WEDNESDAY EVENING, December 9th.—The INFANT MINSTRELS! The MASTERS HUGHES.—At the request of several families these astonishing children will give two more CONCERTS; which will take place on the 9th and 11th inst.

PROGRAMME—PART I.

Solo—Harp—The celebrated Welsh Air, "Ar hyd y nos," (or Poor Mary Ann.) with Variations, composed and performed by Master H. goes. Master E. Hughes

Solo—Harp—"Beauty in Tears," with Variations composed and performed by. Master David Hughes

Duet—Two Harps—"The Alpine Sauter's March," Air with Variations—"Jenny Jones," . . . The Infant Violinist

Solo—Concertina, The favorite Moore's Melody—"Believe me if all those endearing young charms," with Variations composed by. Master Hughes

American Air—In imitation of a Musical Box on a Welsh Dulcible Harp, Master David E. Hughes, his own arrangement.

Fantasi—Grand Military March, in which Master Hughes will introduce all the new Harp effects. . . . Master Hughes

Solo—Violin—"The Cuckoo Solo," The Infant Violinist

PART II.

Grand Overture—Harp and Concertina, Fra Diavolo.

Trio—The light of other days, and Strauss' favorite Waltzes, La Rose.

Solo—Harp—"Isle of Beauty," Master David E. Hughes—Variations composed by himself.

Solo—Harp—"The favorite Welsh Melody," "The kind Minstrel," with variations composed by. . . . Master Hughes

(By desire)—Harp and Concertina—A sacred Funeral Theme, in which Master Hughes will imitate the muffled drums on the harp, and the solemnity of a military funeral.

Concerto—On two harps at the same time—"The rising of the Lark," for which Master Hughes gained a prize at the London Festival.

Solo—Violin—A favorite Irish Air, with variations. The Infant Violinist

Solo—Concertina—Malibran's favorite air, with variations, by De Beriot. Master Hughes.

Napoleon's Grand March while crossing the Alps—in imitation of the marching of troops and band—th it approach and retreat, until the music entirely recedes upon the air

Finale—Meesley—Harp and Violin Concertina.

To commence precisely at 7 o'clock. Tickets 50 cents.—Children half price. 49 11

Figure 5. Advertisement for a Hughes family performance in New York City, 1840. This event was among the earliest appearances of the concertina in America, although Figure 6 shows an advertisement for a yet earlier concertina performance, in 1839. From the New York Herald, Dec. 9, 1840.

APOLLO SALOON—THE RAINIER FAMILY, known as the Tyrolese Minstrels, will give a Musical Entertainment composed of National Songs, Ranz de Vaches, and Melodies of the Alps, on Thursday evening, Dec. 12, at the Apollo Saloon, 410 Broadway.

Mr. Ernest, the celebrated Flute player to his Royal Highness the Duke of Cambridge, will play a solo on the Flute, and also on the new instrument called the Concertina.

Doors open at 7—Entertainment to commence at 7½ o'clock. Tickets, at 50 cents, to be had at the principal music stores, and at the door, with programme, on the above evening. d11-1m*

Figure 6. Advertisement of a performance on the concertina by a Mr. Ernest, whose concert preceded the arrival of the Hughes family by one year. New York Morning Herald, Dec. 11, 1839.

Notes

¹ This article first appeared in the Papers of the International Concertina Association, Allan Atlas, ed., vol. 4. 2007. I am indebted to Ivor Hughes for the engraving of the young David Edward Hughes, as well as for other information about the history of the family. My thanks also to Randall Merris, who kindly provided information from the census and immigration records for the Hughes family.

² This and the two excerpts from the reviews that follow come from the Charleston newspaper *The Southern Patriot* for 9, 12, and 15, 1845.

³ Other early Hughes family concerts found in period accounts, all since the original release of this study, are noted as follows: *New York Herald*, Dec. 9, 1840; Washington DC *Daily National Intelligencer*, Feb. 12 1841, March 8 1841, and April 24, 1843, City News; *The Weekly Raleigh Register and North Carolina Gazette*, April 2 1843; *New York Herald*, July 27, 1843.

⁴ The earliest concertina performance yet documented in the US is an 1839 performance in New York by a Mr. Ernest (see Figure 6). The next documented appearance of the English concertina in the United States comes with Richard Hoffman's New York City concert on 25 November 1847; see Allan W. Atlas, *The Wheatstone English Concertina in Victorian England* (Oxford: Clarendon Press 1996), 8, n. 54, who, taking Hoffman's publicity at its word—"Richard Hoffman will have the honor of introducing to the American Public [a] New Musical Instrument called Wheatstone's Patent Concertina—refers to Hoffman's concert as the concertina's United States debut.

Additional note: since publication of this Hughes study in PICA, another still earlier concert by a 'Mr. Ernest' at the Apollo Saloon in New York has come to light. Advertised in the New York Morning Herald of Dec. 11, 1839, it predates both Hoffman and the Hughes family. 'Mr. Ernest, the celebrated flute player to his Royal Highness the Duke of Cambridge, will play a solo on the flute, and also on the new instrument called the Concertina.' He had second billing to the Rainier Family Tyrolese Minstrels.

⁵ Brian Bowers, *Sir Charles Wheatstone, FRS 1802-1875*, rev. ed. Institution of Electrical Engineers History of Technology Series, 29 (London: Institution of Electrical Engineers, 2001), 232.

⁶ I have drawn on the following for the basic outline of Hughes's life: 'Obituary, David Edward Hughes', *The Electrician* (London), 26 January 1900, 457-58 (online at <http://Earlyradiohistory.us/1900/hugh.htm>); *Dictionary of National Biography*, xxii (London: Smith, Elder, 1906), 877-79; and two websites: Ivor Hughes and David Ellis Evans, 'A Welshman Who Became World's First to Transmit and Receive Radio Waves' at

www.rootsweb.com/~vtwags/DEHughes.html; and unsigned, '100 Welsh Heroes' (National Library of Wales), at www.100welshheroes.com/en/biography/davidedwardhughes.

⁷ London, Horniman Museum, Wayne Archive, Wheatstone sales ledger 104a, p. 5; the sale is for Wheatstone concertina No. 100; the ledgers are online at www.horniman.info.

⁸ Washington, D.C., National Archives and Record Administration, Registers of Vessels Arriving at the Port of New York from Foreign Ports, 1789-1919. Micropublication, M237, rolls 1-95. This information can be accessed online at www.Ancestry.com.

⁹ 'New Strand Theatre', *The Times*, 18 February 1832.

¹⁰ Personal communication from Ivor Hughes, January 8 and 9, 2007.

¹¹ At the risk of claiming too many 'firsts': the advertisement seems to contain the earliest image of a concertina as part of a musical ensemble.

¹² ‘Obituary’, 457. I have not been able to identify Herr Hast.

¹³ The publisher was G.W. Brainard & Co.; a copy of the original print is preserved in the Dwight Anderson Music Library, University of Louisville (KY); communication of 8 January 2007 from Ivor Hughes.

¹⁴ ‘Obituary’, 458.

¹⁵ ‘Obituary’, 457.

¹⁶ Bowers, *Sir Charles Wheatstone*, 148-50.

¹⁷ Though Bowers’ work is the definitive biography of Wheatstone, it is worth consulting the Wheatstone entry in ‘Wikipedia’;: http://en.wikipedia.org/wiki/Charles_Wheatstone .

¹⁸ ‘Obituary’, 458

¹⁹ Bowers, *Sir Charles Wheatstone*, 119.

²⁰ John Munro, *Heroes of the Telegraph*. (Seattle: Worldwide School Library, 1997), Ch. 10.; one of the best resources for technical descriptions of Hughes’ inventions, Munro’s work is available online at www.worldwideschool.org/library/books/tech/engineering/HeroesoftheTelegraph.html.

²¹ R.J. Brown, ‘Alexander Graham Bell and the Garfield Assassination’, online at www.historybuff.com/library/refgarfield.html; see also, *Today in History: July 2, 1881: ‘American Memory’*, Library of Congress, online at <http://memory.loc.gov/ammem/today/jul02.html>.

²² Tom Farley, ‘Digital Wireless Basics, Telephone History’, Ch. 3: ‘Early Radio Discoveries’; online at www.privateline.com/PCS/history3.htm

²³ R.W. Simons, ‘Guglielmo Marconi and the Early Systems of Wireless Communication’, *General Electric Company Review*, xi/1 (1996); online at www.marconi.co.uk.

²⁴ ‘Obituary’, 458.

²⁵ *Popular Science Monthly*, August 1922, 57.

²⁶ ‘Obituary’, 458. Other awards include those from Italy, the Order of St. Maurice and St. Lazare, awarded by the king, 1862; Austria, Order of the Iron Crown, awarded by the emperor; Russia, Commander of the Order of St. Anne, 1883; Germany, the Noble Order of St. Michael, in Bavaria and Württemberg; Turkey, Grand Cross of the Medjidie, from the Sultan; and similar honors in Switzerland, Belgium, and Spain.

²⁷ *Dictionary of National Biography*, xxii, 877-879.

²⁸ *Dictionary of National Biography*, xxii, 879.

²⁹ ‘Obituary’, 458.