Introduction
The Laboratory and the Stage

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At first sight, opera and science would seem to occupy quite separate spaces. The one typically unfolds on the stage of a theatre, the other most often takes place in a laboratory or lecture hall. The one draws on creative inspiration in entwining music, poetry and spectacle, the other on inductive reasoning through observation and experiment; patient activities that, for John Herschel in 1831, constituted the 'fountains of all natural science'.[1] And while the one offers an opportunity for emotional and intellectual engagement through the public gaze, the other cautiously validates the empiricism of verifiable experience through critical acts of witnessing. To yoke the two together, then, may appear arbitrary.

Yet such a view not only risks caricature through its stark oppositions, but also overlooks a scene of rich interconnection within nineteenth-century European social and intellectual life. To start at the biographical level, we find a famous scientist such as Michael Faraday not only regularly attending the opera during the 1830s, but also passing judgment in his correspondence on works such as *Fidelio, Il barbiere di Siviglia, Lucrezia Borgia, Les Huguenots* and *L'Étoile du Nord*, while collaborating with Charles Wheatstone in lectures on acoustics at London's Royal Institution.[2] Or take the Victorian polymath Herbert Spencer, who would voice loud opinions on quantifiable 'originality', arguing, for instance, that Meyerbeer's operas were less 'hackneyed' than Mozart's keyboard sonatas.[3] At the same time, composers such as Berlioz and Borodin undertook significant scientific training, the former (unwillingly) in medicine, the latter (enthusiastically) in chemistry – a field in which, for twenty-five years, he held a chair at the Medical Surgical Academy in St Petersburg.

In the context of institutions, meanwhile, a book published in 1908 by two scientific practitioners, entitled *La Science au théâtre*, justified its subject on the basis that 'the applications of science in the theatre are

1 Herschel 1831, 76.

2 See Faraday's letters 2835, 2991, 3009, 3448, 3455 in F. James 1991, 4:684, 871, 888, and 5:388, 391.

3 Spencer 1902, 114.

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today so numerous, the scenic reproduction of natural phenomena so perfect, [and] effects of all kinds so ably executed' that a study of procedures, devices and machines seemed worthwhile for the theatre-going public.[4] Such a call echoed the opinions of Gaston Tissandier, editor of the eminent journal *La Nature* (founded in 1873). Having completed recent articles on subjects as diverse as the manufacture of artificial butter and the chemical properties of snowflakes, in early 1875 Tissandier turned his attention to the recently inaugurated Garnier opera house in Paris, on the basis that 'all branches of physics are represented at the new Opéra: heating, lighting, optics, electricity, acoustics [all] play different parts in it'.[5]

The following fourteen essays contained in this book advance many more examples of such intersections, with a large cast of both scientists and musicians, famous and forgotten, and touching on topics from vocal physiology to theories of mental health, and from urbanisation to hypnotism. Yet the separation of the two fields can still seem deep-set, for a variety of reasons that themselves have their roots in the nineteenth century and that deserve further attention. These include an approach to opera centred on composers and their works, rather than on performers and performances, but can also be linked to a scientific understanding of sound that sets it apart from romantic opera's quest for 'the magic force of poetic truth', as E. T. A. Hoffmann put it in 1813.[6] At the same time, as numerous contributors here attest, opera's tendency towards excess – whether in terms of voice or spectacle – has frequently made it an object of scholarly suspicion for scientists and musicologists alike, to the point that even a work as inclusive as Guido Adler's famous musicological manifesto of 1885 hides opera within a small subset of his study of 'basic historical categories'; well away from the study of 'systematic musicology', with its 'auxiliary sciences' of acoustics, mathematics, physiology, psychology, logic, metrics, pedagogics and aesthetics.[7]

Such separations, of course, also fit neatly within the standard divisions between the Humanities and Natural Science, whether figured as 'two

[4] 'Les applications de la science au théâtre sont aujourd'hui si nombreuses, la reproduction scénique des phénomènes naturels si parfaite, les trucs de tous genres si habilement exécutés.' Vaulabelle and Hémardinquer 1908, 1. Vaulabelle was a scientific writer, Hémardinquer a physicist.

[5] 'Toutes les branches de la physique sont représentées au nouvel Opéra: la chaleur, la lumière, l'optique, l'électricité, l'acoustique y jouent des rôles différents.' Tissandier 1875, 150. The previous two articles by Tissandier on the same topic addressed 'Ventilation and Heating' and 'Gas and Lighting': a reminder of the ways that the meeting of science and opera also brings us towards aspects of the operatic industry unfamiliar from traditional histories.

[6] Hoffmann 1963, 788. [7] Adler 1885, 5–20; Eng. trans. Mugglestone 1981, 1–21.

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cultures' or as a natural result of specialisation, with the result that one might be tempted to rephrase the aim of this book as an integration of two parallel but separate cultural scenes: two tributaries in search of a single river. Yet we argue instead that at this time the river already existed, and that discourses of science and opera already overlapped, only later to be channelled into separate streams. Both, for instance, strove for universals. Some writers on music, such as Giuseppe Carpani in 1821, fantasised about opera itself – here in the form of the melodies of Rossini – as a universal force; spreading beneficently throughout the world, freely floating over the seas, and in a short time 'mak[ing] the circuit of the earth, touch[ing] on every shore, and enter[ing] every port'.[8] Others, like Arthur Schopenhauer – another Rossini fan, though one who would dub opera 'an unmusical invention' – would be unequivocal in labelling music 'a universal language which is understood everywhere, so that it is ceaselessly spoken in all countries and throughout all the centuries with great zeal and earnestness'.[9] Charles Darwin, in similar terms, would argue that a shared biological origin was the guarantor for the universal nature of all human expression and emotion.[10] And some decades earlier John Herschel (keen composer and violinist) spoke of 'those universal axioms which we aim at discovering', and cited the law of gravitation as the 'most universal truth' at which human reason has yet arrived, in permitting the most precise quantitative statement: 'not merely the vague statement that its influence decreases as the distance increases, but the exact numerical rate at which that decrease takes place'.[11] Leaving aside the philosophical distinction between what is given (discovered) and what is made (invented), we argue that such parallelism exceeds mere semblance. Instead it bears witness to a shared universalising impulse with its roots in the eighteenth century that would be simultaneously discharged in different directions in the nineteenth: through the urge to communicate on the one hand, and a desire for knowledge of natural laws on the other.

Not that 'opera' and 'science' were themselves in any way stable categories in this period, of course. The operatic long nineteenth century – stretching from Mozart and Rossini via Verdi and Wagner all the way to Puccini and Strauss – can give an illusion of uniformity in its position as the backbone of the twenty-first-century operatic canon. Yet in its course,

[8] 'fa ben tosto il giro della terra, abborda a tutt'i lidi; entra in tutt'i porti'. Carpani 1822, 302–3.

[9] Schopenhauer 2004, 162. His proof was far from empirical: the ready comprehensibility of a 'significant melody which says a great deal . . . [proving] that the content of a melody is very well understandable'.

[10] Darwin 2009, 329ff. [11] Herschel 1831, 123.

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this is a history that encompasses not just a variety of genres – including *opéra comique*, operetta, grand opéra and music drama – but that also saw an explosion of operatic performance inside and outside the opera house across Europe and around the world.[12] And the conception of science remained equally in flux: in 1824, for example, when the term 'Naturwissenschaft' appeared for the first time in Brockhaus's lexicon it received the following pithy definition: 'Nature is mirrored in the spirit of the cultivated person, and this reflection, this ideal image of nature, is natural science.'[13] The combination of nature, her beauty and lawfulness mirrored in cultivated human nature created a triad of contemporary values that were embodied in the emergent persona of the *Naturforscher* ('physicien' and 'naturaliste'/'natural philosopher'), someone who in learning and specificity of purpose exceeded the dilettante butterfly collectors and brilliant amateur polymaths of earlier generations. But as Denise Phillips has shown, while the word 'science'/'Wissenschaft' took on its modern meaning during the course of the nineteenth century, and while ideas of a unified science became associated with mid-century figures such as Du Bois Reymond, Helmholtz and the students of Johannes Müller, 'the power of the term came in part from its continued ambiguity'.[14]

This ambiguity is to some extent a fact of continuous development. As is well known, it is precisely during the nineteenth century that the scientific enterprise underwent unprecedented intellectual and social changes. This is partly reflected in the emergence and professionalisation of the differing disciplines of chemistry, biology, physics, medicine, physiology and the earth sciences, whose public presence became manifest in the formation of national institutions (such as the Royal Institution in London, established in 1799, the Schweizerische Naturforschende Gesellschaft in Geneva, established in 1815, the Kaiserliche Akademie der Wissenschaften in Vienna and the Real Academia de Ciencias Exactas, Físicas y Naturales in Madrid, both established in 1847, as well as the American National Academy of Sciences, established in 1863) and university curricula, and partly through the vast efforts made at disseminating knowledge through popular lectures and a wide range of non-specialist publications. Everything from natural philosophy, literature and educational methods, to military strategy – and, of course, music – became implicated within the scientific enterprise. And so did their agents. Singers seeking vocal enhancement or a cure for loss of voice turned to chemical treatments and physiological experiments; composers experimented with new

12 See Osterhammel 2014, 5–7. 13 [unsigned] 1824, 6:740–7. 14 Richards 2012, 9.

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instruments; machinists sought out new scenic effects. In daily life, meanwhile, composers and performers came to rely on developments in medicine and applied science as much as any other sector of society. Berlioz and Wagner, for instance, both underwent 'galvanic' treatment for ailments; Wagner also reluctantly recommended train travel and steamers to friends as the fastest means of getting around, just as opera houses newly linked through networks of rail lines advertised for wider audiences, and steam-powered seafaring facilitated touring companies in travelling further afield.[15]

Our concern here, however, is not just a matter of opera and its personnel interacting with and responding to claims for scientific universalities and technological developments. Instead, we argue for a more complex reciprocity, in which operatic production and performance is transformed and reframed by its contact with a variety of scientific (and pseudo-scientific) thought, and where different branches of science are informed and shaped by their contact with opera, broadly conceived. For our purposes, that breadth supports a definition of opera easily encompassing vocal pedagogy, opera house architecture and stage machinery as much as music and drama. It also, in several of the chapters here, conjures a real of the 'operatic' that extends on the one hand towards dramatic instrumental music (such as Berlioz's *Symphonie fantastique*), and on the other the sorts of spectacular allegorical dances that shared the stages with sung drama on many of Europe's great opera houses during the period.

Underlying such variety, the broad questions in pursuit of universals gained urgency as the century wore on. 'Light and tone are the building blocks of art,' explained Eugen Dreher in his 1875 reflections on the relationship between art and natural science. 'In order to understand artistic works philosophically, though, we must unavoidably turn to the physical part of light and tone, and see whether we can use the laws of optics and acoustics to conceive a theory of art with their assistance.'[16] And if such a statement emerges somewhat flat-footed, in a rational tract, it mirrors earlier, flightier forays in the form of fiction. In 1837, for example, one of Balzac's most musical short stories, 'Gambara', depicts an aging composer and instrument builder whose unperformed opera sounds radiant on his new, retuned instruments, but cacophonous on those in common usage. 'Music is at once a science and an art,' Gambara tells his

[15] Walter 2016, 51–2.

[16] 'Licht und Ton sind somit das Baumaterial der Kunst. Um aber die Kunstschöpfungen philosophisch zu verstehen, müssen wir nöthgedrungen auf den physikalischen Theil von Licht und Ton eingehen und sehen, ob wir die Gesetze der Optik und Akustik gebrauchen können, um mit ihrer Hilfe eine Theorie der Kunst zu entwerfen.' Dreher 1875, 23.

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curious Italian patron. 'Its roots in physics and mathematics make it a science; it becomes an art by inspiration which unconsciously employs the theorems of science. It derives from physics by the very essence of the substance it employs: *sound is air modified*.'[17] Such a potted definition of the mechanical propagation of acoustic waves chimes with experiments by the likes of Chladni and Wheatstone, and pre-empts those of Helmholtz, John Tyndall and Alexander Ellis.[18] Yet Balzac's optimism for the potential of acoustic science would prove more speculative than that of his scientist counterparts:

> What heights could we not attain if we were to find the physical laws by virtue of which – consider this! – we collect . . . a certain ethereal substance, diffused within the air, which affords us music as well as light, the phenomena of vegetation as well as those of zoology! . . . Those new laws would arm the composer with new powers, offering him instruments superior to those he has now, and perhaps a more wondrous harmony compared to the one which governs music today.[19]

A smattering of orphan music technologies emerged under the auspices of such rhetoric. These included real new instruments, from melographs and the melodium, to orchestrions such as Johann Nepomuk Mälzel's panharmonicon (a large mechanical orchestral organ), Dietrich Niklaus Winkel's Componium (an algorithmic generator of melodic variations), Johann Jakob Schnell's *anémocorde* (an elongated keyboard whose strings were vibrated by compressed air), and Angelo Barbieri's automatic organs intended for churches unable to afford an organist.[20]

To be sure, such new instruments rarely if ever established themselves in the opera house pit (though they may well have been put to the task of performing operatic arrangements). Instead we have unsuccessful attempts like the glass harmonica intended for *Lucia di Lammermoor* (1835) that had to be rescored for two flutes in Donizetti's autograph manuscript, for

[17] 'La musique est tout à la fois une science et un art: les racines qu'elle a dans la physique et les mathématiques en font une science; elle devient un art par l'inspiration qui emploie à son insu les théorèmes de la science. Elle tient à la physique par l'essence même de la substance qu'elle emploie, car le son est de l'air modifié'. Balzac 1837, 359; Eng. trans. 2001, 77; emphasis added.

[18] See, for instance, Chladni 1787; Tyndall 1867; Ellis 1885; Helmholtz 1954; and Wheatstone 2011b.

[19] 'où n'irions-nous pas si nous trouvions les lois physiques en vertu desquelles (saisissez bien ceci) nous rassemblons . . . une certaine substance éthérée, répandue dans l'air, et qui nous donne la musique aussi bien que la lumière, les phénomènes de la végétation et de la zoologie! . . . Ces lois nouvelles armeraient le compositeur de pouvoirs nouveaux en lui offrant des instruments supérieurs aux instruments actuels, et peut-être une harmonie grandiose comparée à celle quie régit aujourd'hui la musique.' Balzac 1837, 359; Eng. trans. 2001, 78.

[20] See Dolan 2008, 11–12; Trippett 2013, 96–100; Farabegoli 2016, 59–71.

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instance.[21] And when Meyerbeer first incorporated a church organ into *Robert le Diable* (1831), *Le Figaro* branded it a 'sublime invasion of the domain of the Opéra', where the shock arose more from cultural disorientation, from repurposing the soundtrack of ecclesiastical worship, rather than from scientific novelty per se.[22]

Yet Balzac's original conception of Gambara's super-instrument leads us beyond such specifics, expanding in Balzac's freewheeling text not only to include voices as well as multiple instrumental parts, but also reaching towards the idea of Meyerbeerian grand opéra as itself 'a gigantic, unified machine', as Emily Dolan and John Tresch have suggested.[23] Such a view accords with Tresch's broader image, developed in his monograph *The Romantic Machine*, of a transformed post-Napoleonic understanding of machines as 'flexible, active, and inextricably woven into circuits of both living and inanimate elements'.[24]

This line of research, with its close imbrication of romanticism and industrialisation, and its insistence on breaking down boundaries not only between art and science, but also between opera and other artistic and technological developments (the daguerreotype, the automaton and so on), forms a key precursor to the sort of approach that we pursue here. But it is not the only one: Wagner scholarship, after all, had been switched onto technological questions at least since Adorno's *In Search of Wagner* (drafted, in part, during 1937–8), with its analysis of the Bayreuthian concealment of technology and labour through novel instrumentation as well as the hidden orchestra, the loss – for Adorno – of individual identity in the body's physiological response to mediatised sounds – sounds studded by leitmotifs, repeated advert-like, for the purpose of dulling critical faculties (i.e. mirroring – for Adorno in 1938 – the propaganda mechanisms of National Socialism), the darkened auditorium and the pursuit of a controlling, proto-cinematic illusion. Hence when Friedrich Kittler sketched out both a history of operatic lighting and an argument for the analogue orchestra modelling electronic amplification, Wagner remained at the centre, as he would in Carolyn Abbate's second book, whose title pays homage to Adorno's example and follows Kittler's provocative analysis of moments of Wagnerian sonic climax vis-à-vis media, from rock amplification to Zeppelin bombers.[25] Yet while Abbate's *In Search of Opera* remains perhaps the richest and most

[21] See Smart 1992, 129.

[22] 'L'Orgue qui a fait une sublime invasion dans le domaine de l'Opéra.' [unsigned] 1831, 2–3; cf. Coudroy-Saghaï 1988, 62.

[23] Dolan and Tresch 2011, 9. [24] Tresch 2012, xi. [25] Abbate 2001; Kittler 2013.

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suggestive study of nineteenth-century opera and technology to appear in recent years, it nevertheless leaves a gap between *Die Zauberflöte* and Wagner's music dramas that Tresch and others have only recently begun to fill.[26] More generally, although both Adorno and Abbate proceed from a desire to demystify Wagner in a way that from one perspective harks back to the sort of unveiling of stage trickery found in earlier books like *La Science au théâtre*, the familiar orbit around Bayreuth and its associated dramatic innovations risks overlooking not just the wider operatic histories of the period, but also the intersections of those histories with a wide variety of both technologies and theories outside the Wagnerian purview.

Wagner is not neglected in the present study. But across the essays we have tried to bring together a variety of different kinds of approach to the study of opera and science that both reflect the variety of recent work in what is a fast-growing field, and that also seek to indicate future directions. Given the diversity of our topic, moreover, we make no claims here either to full chronological or geographical coverage. Instead, we have sought a selection of case studies that engage with – or else offer alternatives to – existing narratives whose key events are by now well established. One such narrative, outlined by Kittler and others, is the history of operatic technology (specifically lighting), with a special place reserved for the inauguration of dimmable gaslight at the Paris Opéra for Nicolas Isouard's *Aladin ou La Lampe merveilleuse* (1822), thereby permitting a darkened auditorium that refocused onlookers' sensoria, and demanded a new sensory engagement with the unfolding production, as though the magical lamp doubled as a quasi-Promethean gift. (It is indicative of applied science's transformative impact on daily life that, prior to the invention of yellow phosphorus matches in 1805, fires and lamps were still lit by flint, steel and tinder, a method dating back millennia.) By the mid-century, carbon electric arc lamps allowed for an unprecedented intensity of illumination that rendered naked flame passé. The spectacular electric sunrise in the third act of Meyerbeer's *Le Prophète* (1850) then 'doomed' to inadequacy earlier candle- and gas-powered effects in the prologue to Verdi's *Atilla* or in the ode-symphonie to Félicien David's *Le Désert*, as Anselm Gerhard and others have noted.[27]

[26] A representative sample of such works includes Jackson 2006; Smocovitis 2009; Hui 2012; Steege 2012; Tresch 2012; Hui, Kursell and Jackson 2013; Pesic 2014; Davies and Lockhart 2016; Henson 2016.

[27] Gerhard 2000, 299. Cf. Loughridge 2016, 11ff.

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If staged optical illusions proliferated from the possibilities of controllable lighting technologies, from realist dioramas (including shimmering clouds in Meyerbeer's *L'Africaine*[28]) to panoramas, magic lantern shows and the two locomotive boilers that created steam effects for the *Ring* at Bayreuth,[29] another, more concealed operatic history of hallucination and hypnotism had a less deterministic influence. This might draw a tentative connection between depictions of ghosts and spirits (*Der Freischütz, Undine*), visitations (*Les Troyens, Palestrina*) and – somewhat later – séance (*The Medium*), merging audience association of occult practices offstage with their sometimes all-too-material aesthetic representation onstage, all amid the cult of visual phantasmagoria that had become intrinsic to the reinvention of grand opéra during the 1830s.[30] Later in the century, we might look for another shadow history in the use of novel acoustic effects in Wagner's depiction of three-dimensional soundscapes (*Lohengrin*, *Die Meistersinger*, *Parsifal*), and artificially enhanced auditory communication implied at the close of Schreker's *Der ferne Klang* (1903), for moments of interchange between scientific knowledge and operatic production.

If these each represent stories yet to be fully pieced together, it is also important to stress that the thematic interrelation between opera and science could also on occasion be disarmingly explicit, as explored here in Deirdre Loughridge's chapter on late eighteenth-century 'scientific' operas. A further notable instance occurs in *The Devil's Opera* (1838), George A. Macfarren's first musical drama, whose commercial success was credited with saving the fortunes of London's ailing Lyceum Theatre. Midway through Act I, the bass Posillipo, a Venetian noble, is planning an occult experiment for the evening, which he anticipates will bring him immortality. Sitting at his desk amid the accoutrements of scientific learning – 'books, globes, telescopes, chemical apparatus, skeletons . . . skull, hourglass' – it is his dark pact with 'science' that paves the way:

[28] A handwritten addition to Meyerbeer's manuscript for *L'Africaine* reads: 'At this moment the branches of the manchineel open and one sees through transparent foliage the dream of Sélika in action: from the two opposing sides of the theatre, one sees two group of shimmering clouds, one over the top where Sélika is set, the other on the bottom where Vasco is set. The cloud supporting Vasco rises while Sélika's lowers (on a diagonal line), and they become one as they meet.' Cited in Cruz 1999, 46–7.

[29] See Kreuzer 2011.

[30] On the problematic materiality of the effects in Weber's *Der Freischütz*, see Newcomb 1995.

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Hail science! Potentate sublime!
Schoolmistress, that all knowledge teaches!
Freeholder of all space and time,
And banker of all wisdom's riches!
Inspired, and cherished by thine aid,
To seek what ne'er was sought before,
A weary pilgrimage I've made
Through all the realms of learned lore:
Mathematics – hydrostatics –
Pyrotechnics and pneumatics –
Metaphysics – economics –
Necromancy and mnemonics –
Necrology –
Astrology –
Meteorology –
Demonology! –

At length I reached the happy goal;
At length, by my endeavor,
Stern Death shall have no more control,
And life shall last for ever!

When this premiered on 13 August 1838, its gesture towards the wonders of science was evidently plausible. The first season ran for fifty nights, and its second for thirty.[31] Posillipo's eulogy is consistent, perhaps even repetitive (in the second act, we find 'Science! Thou queen of mysteries! Let thy phosphoric lantern penetrate this double darkness . . . Science pays all, and ennobles the world.'[32]), though at least one critic dismissed the libretto as so much hocus-pocus, 'a succession of pantomime tricks', and advised the composer to seek a better poet (it was his father).[33]

Scientists, though, were not immune from the power of theatre and the well-timed pantomimic revelation, as can be seen in the growth through the century of public scientific demonstrations and public lectures. 'Science lecturing was a competitive business', as Bernard Lightman has pointed out. 'Not only were lecturers competing with one another to draw audiences, they were also vying with the theater, the panorama, the exhibition, museums, and other forms of popular entertainment.'[34] Naturally, such

[31] Bennett 1897, 454. [32] Macfarren 1838, 23–4. [33] [unsigned] 1838, 197.
[34] Lightman 2007, 125.

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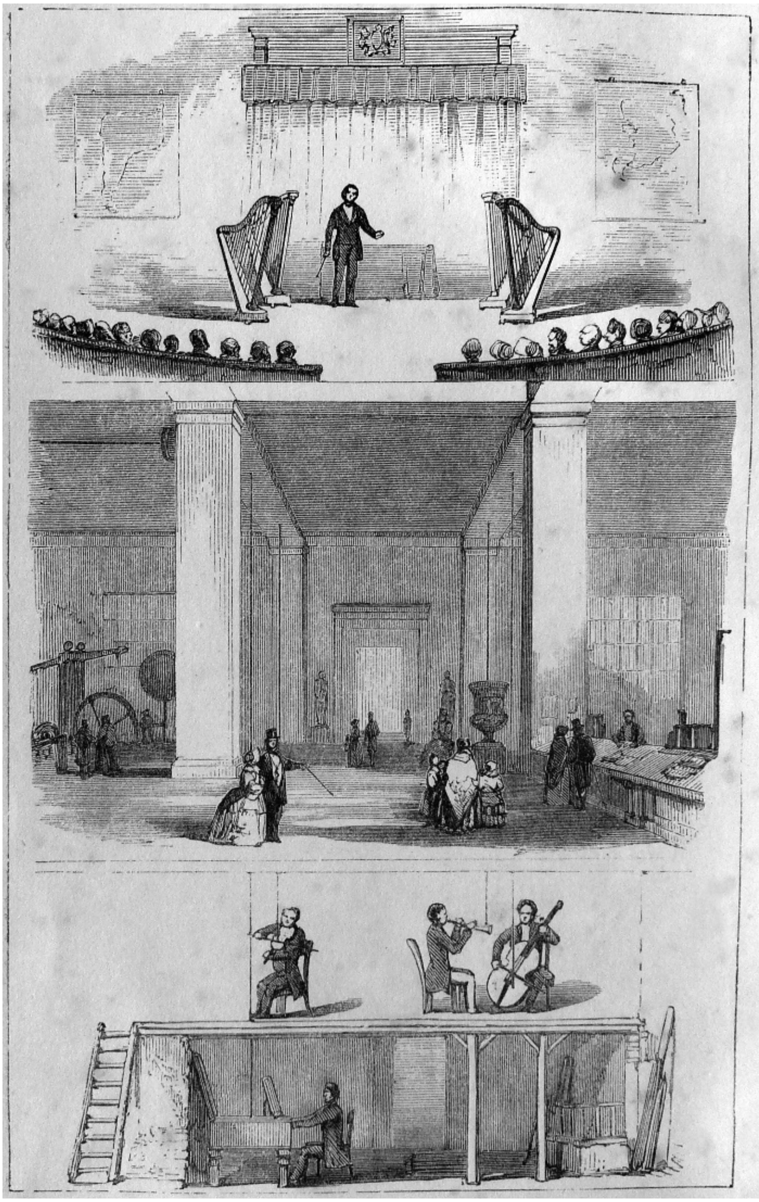

Figure I.1 A demonstration of Charles Wheatstone's 'Enchanted Lyre', The frontispiece to John Pepper, *Boy's Playbook of Science*, 2nd edn. (London: George Routledge and Sons, 1866), Whipple Library, University of Cambridge.

lectures included those on acoustic science. A well known example, shown in Figure I.1, is Charles Wheatstone's 'Enchanted Lyre' that appeared to play itself when suspended by strings from the ceiling, but was in fact stimulated

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into sonorous resonance by concealed, interlocking metal rods that conducted vibrations produced in an adjacent room. John Henry Pepper's illustration of this illusion – with four harps – formed the frontispiece for his best-selling primer *Boy's Playbook of Science* (1860), where he wrote of Wheatstone's 'telephone concert . . . in which the sounds and vibrations pass *inaudible* through an intermediate hall, and are reproduced in the lecture-room unchanged in their qualities and intensities'.[35] Such demonstrations of acoustic illusion could claim separation from straightforward scientific fraud (such as Wolfgang von Kempelen's famous chess-playing Turk), in that the rational basis of the illusion remained; the one used ingenuity to apply uncommon knowledge for dazzling effect, the other did the same without any claim for scientific truth. Yet the parallels remained, and were foregrounded in cities in possession of fewer theatres than London or Paris, where a single institution might stage an opera one night, a spoken play the next and an exhibition of scientific experiments the third.[36]

Back in the vast metropolis of London, Wheatstone's spectacle entertained street audiences in London's Pall Mall district as well as professional scientists at the Royal Institution, and a general public at the Royal Polytechnic Institution's lecture theatre. Founded in 1838, the Polytechnic (later the University of Westminster) was a commercial enterprise specifically for displaying novel invention and eye-catching demonstrations. Located at 309 Regent Street in the heart of London's commercial district, its mixture of authoritative scientists, such as Faraday, and showmen, such as Pepper, meant that it trod a delicate line between theatrical display and didactic demonstration.

Perhaps the most salient phenomenon to dovetail demonstration with operatic spectacle was the so-called 'Pepper's ghost'. Pepper, whom we met above, popularised an illusion (invented by Henry Dircks) in which a large piece of plate glass placed at forty-five degrees to an audience gave the illusory appearance of a ghost when lighting for a concealed second actor was closely controlled. This device was first used in stage plays (Charles Dickens's *The Haunted Man*, 1862, and later, adaptations of *A Christmas Carol* and Goethe's *Faust*) but also migrated to operas, including canonical works such as *Der fliegende Holländer* and *Der Freischütz*, as well as once-familiar hits such as John Barnett's *The Mountain Sylph* and Michael William Balfe's *Satanella*, based on a female demon.[37] There was even

[35] Pepper 1866, frontispiece.

[36] This was the case, for instance, in various port cities of the Americas during the 1820s, when Italian opera was being performed for the first time.

[37] Burdekin 2015, 158.

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a dedicated touring company formed in 1869 entitled The Original Pepper's Ghost and Spectral Opera Company, whose performers travelled widely in Great Britain and Ireland.[38] It is indicative of both public expectation and the appeal of such effects that Wagner's seafaring tale was explicitly advertised in Exeter as having 'great scope for the introduction of Optical illusions, Scenic and Mechanical Effects'.[39] And that, thirteen years after Meyerbeer's electric sunrise, Pepper would deploy a modified arc lamp technology to illuminate Trafalgar Square and St Paul's Cathedral for the wedding of Edward Albert, Prince of Wales, and Alexandra of Denmark.

The closer the investigation of the interactions between science and opera, in other words, the more intertwined the two become, to the point that any distinction between public scientific demonstrations and operatic or theatrical performance becomes blurred. Just as scientists reached for the revelatory tricks of the theatre to hold their audiences entranced (or else, like Charles Darwin, described the wonders of tropical scenery through comparison with the opera[40]), so books like *La Science au théâtre* sought to explain the mechanics of the theatre as a way to replace one form of enchantment (based on aesthetic appreciation) with another (based on the technological sublime).

Faced with such enchantment, there is a temptation for the twenty-first-century historian to treat the intersection of science and opera as an invitation to bask in the wonder of once-novel technologies, in pursuit of a time before opera irreversibly lost its place to cinema as the most visually (and sonically?) spectacular of artforms. And sure enough, in the course of this book we invite the reader to marvel at the union of dance, technology and scientific technology in Manzotti and Marenco's 1881 ballet *Excelsior*; to imagine operatic performances designed to alleviate mental disorders, or as part of experiments in hypnosis; to rehear Wagner's music through the novel science of otology as literally deafening; or to rediscover the initial potential of technologies now invisible through their ubiquity, such as electric circuits, or long obsolete, like the original laryngoscopes. Counterbalancing all such invitations to wonder, though, is an underlying insistence on the fundamentally unremarkable nature of all these stories as part of the larger cultural life of the time; a quality that can help to counteract the 'quirky' potential so often lurking within attempts to

38 Burdekin 2015, 156.

39 [unsigned] 1882, 1. On the English phantasmagoric nautical predecessors of Wagner's opera, see Cruz 2017.

40 See Keynes 1988, 69–70; cf. Walton 2018.

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combine the histories of music and science by grounding each chapter within a cultural sphere in which the intersection of opera and science becomes in itself unremarkable.[41]

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There would have been many ways to group the individual chapters here, and we hope and expect that readers will find fruitful connections within and beyond our four broad thematic categories: 'Voices', 'Ears', 'Technologies' and 'Bodies'. Each part privileges thematic congruence over strict chronology, yet some themes (such as hypnosis or degeneration) intentionally resurface in new contexts from one part to another. Taken as a whole, the chapters represent a geographical spread across the main operatic centres of Europe (which for the most part map onto the main centres of scientific research), with occasional forays over the North Atlantic.

We open the first part, on 'Voices', with two chapters exploring the direct influence of science and new technology on the art of operatic singing. Benjamin Steege describes the decades around 1870 as 'a particularly anxious moment in the history of the voice'; a period in which opera's perennial preoccupation with a lost golden age manifested itself in an attempt to transform vocal pedagogy through anatomical and physiological understanding. The adoption of the laryngoscope by the likes of Manuel García *fils* and Emma Seiler opened up the pursuit of correct singing aided by laryngeal observation, with a view to returning to the supposedly lost art of Italian vocal virtuosity, yet at the same time hinting at modernist concerns to come.

Within a similar pan-European (and increasingly transatlantic) context of scientific enquiry, James Q. Davies uses the voice of the great tenor Jean de Reszke to explore the preoccupation towards the end of the nineteenth century with various forms of breath control, and to argue for a history of sound recording that establishes a continuum between the new technologies of reproduction and earlier interests in extracting vocal sounds from the air. In Davies's telling, Reszke's novel breathing method, achieved with the help of medical science, represented a break with techniques of earlier decades, leading to accusations that the singer had wilfully ignored the still-recent revelations of laryngoscopy. This set the stage for a scientific dispute over techniques of vocal production that drew on contemporary racial theory and ultimately spilled over into the

[41] On the risks of quirky histories, see Mathew and Smart 2015.

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advocacy of mass adenoidectomies among the schoolchildren of early twentieth-century New York.

The chapters by Carmel Raz and Céline Frigau Manning turn from attempts to understand and shape the operatic voice scientifically to the uses of the operatic voice as part of scientific research. Raz focuses on the connections between opera and psychiatry by looking at the theatrical productions staged at Charenton in the early nineteenth century, which contributed to a debate among doctors over the benefits of such therapy. In this light, she interrogates two case histories from the 1830s that illustrate contemporary medical ambivalence over the operatic voice as either therapeutic or pathological. Frigau Manning excavates another case history from the other end of the century, in which one of the most renowned baritones of the age, Victor Maurel, explored the connections between voice and gesture through hypnosis. Maurel's experiments, Frigau Manning suggests, reveal some of the ways that the culture of hypnosis exploited the often porous boundaries between experiment and entertainment, science and spectacle, while also shedding new light on Maurel's own psychology of acting.

In the second section, 'Ears', we turn from singing to hearing, and from performers to composers. Julia Kursell explores the role of aural perception in the music of Hector Berlioz, in the context of contemporary physiological theory. In a movement like the famous 'March to the Scaffold' of the *Symphonie fantastique* (an early example of the many operatically saturated non-operatic works that Berlioz would go on to produce), Kursell argues that Berlioz creates the aural effect of a moving band, an acoustic image that challenges the boundaries between the realms of the real and the fantastic, by playing with the boundaries between aural perception and the romantic fascination with supernatural sounds. Similarly, the appearance of ghosts in his grand opera *Les Troyens* can be read as a compositional exploration of sound intensity and timbral expression. Scientific ideas of perception become entwined with a compositional desire to create music from an unreal and imagined world.

David Trippett takes up this interplay between scientific theory and aural effect to explore how acts of listening can be depicted beyond passive silence. The study of auditory mechanisms by Wheatstone, Helmholtz and Tyndall et al. gave rise to mid-nineteenth-century comparisons between the ear and the Aeolian harp – the romantic-automatic instrument par excellence – thereby inviting us to reconsider the many moments in contemporary opera when acts of listening are foregrounded. In this way, the harp becomes not simply the voice of nature, but signifies instead a way

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of relating to nature without reflexive thought, amounting to a kind of automatic audition.

Finally, James Deaville turns to the later nineteenth-century exploration of ear disease and injury to explore how a growing concern with levels of urban noise became enmeshed with complaints about the aural excess of the music of Richard Wagner. Viewed in this light, Deaville suggests, the many representations of Wagner's works as deafening go beyond the realm of comic hyperbole, and instead fit with live concerns about the risks of the excessive volume of modern life, and Wagner's role in contributing to it (a subject given recent topicality by the UK court case in which a viola player at the Royal Opera House, Covent Garden, won damages for the irreversible hearing loss stemming from his participation in the opera house's 2012 *Ring* cycle).[42]

In the third section, we move from modes of perception to the relationships of opera with technology. For Deirdre Loughridge, this involves the exploration of a period in the late eighteenth century during which various operas thematised contemporary scientific fascination with lunar astronomy and balloon flight. For a brief time, Loughridge suggests, science and fantasy could come together on the operatic stage and inform each other, before the magical realms of romantic opera relegated technology back to the wings.

It is here, offstage, that Benjamin Walton's chapter focuses, in seeking to reconstruct the attempts to develop a revolutionary new type of stage machinery for Charles Garnier's grand new Paris Opéra during the decade and more of construction leading up to its inauguration in 1875. The eventual adoption of a machinery system almost identical to that employed for many years in the previous opera house, Walton suggests, invites us to consider the role of failure in the history of operatic technology, and its potential to expand our understanding of opera's material history.

Ellen Lockhart then turns to another hidden story, with ramifications that spill out well beyond the world of opera. She begins, though, with Giacomo Puccini, and his fascination with electricity. While his brief and long-forgotten squib for piano *La scossa elettrica* ('Electric shock'), written for an international convention of telegraph operators, offers few revelations to anyone in pursuit of rich connections between opera and science, it nevertheless points towards what Lockhart terms 'a shared history of music and electricity' running through much of the nineteenth century, and

[42] The judgment on this case, given by Mrs Justice Nicola Davies on 28 March 2018, is recorded here: www.judiciary.uk/wp-content/uploads/2018/03/goldscheider-v-roh-judgmentL.pdf.

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spreading from scientifically inflected Italian aesthetic theories in which music becomes the purveyor of electric effect to descriptions of shared musical listening akin to a séance. Finally, the creation of 'electrical music' was realised in the production of two Italian ballets which thematise scientific discoveries in a way akin to the operas described by Loughridge almost a century before.

The second of Lockhart's ballets, Luigi Manzotti's *Excelsior*, premiered at Milan's La Scala in 1881, also forms the focus of Gavin Williams's chapter, which opens our final section, on 'Bodies'. An entire act of this work is devoted to the subject of electricity, divided into 'The Genius of Electricity' and 'The Effects of Electricity' and concluding with a grand 'Dance of the Telegraph Operators', complete with scoring for a telegraph machine alongside the normal orchestra. Williams's interest, however, is less in the grand narrative of scientific progress enacted on stage (including the invention of the steam engine, the opening of the Suez Canal, and the construction of the Mont Cenis tunnel under the Alps), than in the status of such a work as 'proto-robotic' in its choreography, thereby linking the ballet to the celebration of industry at the 1881 Milan Exposition. In this context, Williams suggests, we can see an exploration of balletic bodies as automata stretching back well before such totemic modernist works as Erik Satie's *Parade* (1917), and can instead reopen an investigation of connections between choreographed (and, by extension, operatic) gesture and a wider range of nineteenth-century urban experiences.

The figure of the automaton similarly forms the focus of Myles Jackson's chapter, which revisits the history of operatic androids, in placing the uncanny fascination of Offenbach's Olympia, in *Les Contes d'Hoffmann*, in the context of nineteenth-century studies in physiology and physiognomy. Where early nineteenth-century anatomists like Sir Charles Bell sought to demonstrate the links between mind and body via the workings of the nerves, later researchers such as Guillaume Duchenne sought to replicate the nervous gestures of emotion through artificial stimulation (electricity again), thereby turning pliant – typically female – medical subjects into Olympia-like mannequins, able to mimic emotions through the application of electrodes.

The last two chapters of the book turn to late nineteenth-century fears of the effects of musical degeneracy. First, James Kennaway echoes James Deaville's attention to the perceived dangers of Wagner's music on its first audiences. But where Deaville addresses the volume of the Wagnerian orchestra, Kennaway turns to the neurasthenic effects of Wagner's music on the brain, and the threat of a resulting loss of willpower. By revisiting the novelty of the Bayreuth experience, Kennaway suggests, with its darkened

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auditorium, we can understand its connections to long-standing preoccupations with hypnotism and other trance states, including the sorts of sensory experiments performed on hysterics at institutions such as Paris's Salpêtrière hospital also mentioned by Jackson. Music, in these terms, became a trigger for a neurological reflex that could lead to mental derangement. And the best escape from such a condition was the successful (and masculine) exercise of willpower to escape the drug-like threat of the Bayreuth experience.

By 1905, the premiere of Richard Strauss's *Salome* only intensified such fears. And as Alexander Rehding argues in the final chapter, critics reached for a language of degeneration grounded in what he terms 'the unholy trinity of nineteenth-century criminal pathology, evolutionary biology and social Darwinism'. What started out as a description of hereditary organic abonormalities, then, turned quickly into a discourse designed to exclude and to vilify. An opera, in these terms, has the potential to itself become a diseased body, subject to dissection from critics determined to reveal all its unhealthy impurities, and brought to life by a composer who has turned away from the romantic imperative to produce truth and beauty, and has instead produced something decayed and degenerate, with the risk of further artistic development along socially damaging lines of a kind that would resurface in the reception of operatic compositions through the early decades of the twentieth century.

Across all the chapters, then, familiar operatic objects, rooted in reception and cultural histories, encounter a newer rhetoric; whether of sonic epistemologies, the complex interfaces of a listening subject, or the agentic capacities of instruments – scientific and musical. The potential unease of classification for such work, we argue, indicates a mutation underway, and we are reminded of Barthes's 'epistemological slide'; his observation that work within the interstices of disciplines eschews the calm of an easy security: 'it begins *effectively* . . . when the solidarity of the old discipline breaks down, perhaps even violently' by ushering in new, contested objects, and a language without a recognisable home.[43] By scrutinising the kind of cultural work that underlies Macfarren's forgotten operatic bass when he cries: 'Science! Potentate Sublime!' we aim to establish new ways for others to pursue an ever more holistic approach to the eddying currents of nineteenth-century operatic and scientific culture.

[43] Barthes 1977, 155; on the challenges and possibilities of musicological interdisciplinarity, see Born 2010.

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