



PHILOMATHS, HERSCHEL, AND THE MYTH OF THE SELF-TAUGHT MAN

by

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The role of technicians and background characters in the historical practice of science is slowly gaining recognition. This paper looks at the collective effort involved in learning science, using as my case study the eighteenth-century musician turned astronomer, William Herschel. Lacking a university education, Herschel, like many contemporaries, presented himself as self-taught, thereby hiding his engagement with a rich network of didactic resources. Placing Herschel's story within the history of pedagogy, I argue that this network, previously discussed only in the context of popular or marketplace science, was an important resource for science education at its highest level.

Keywords: Herschel; education; philomath; fluxions; instrument maker

The heroic tale of William Herschel the musician, who taught himself astronomy, discovered Uranus and founded modern sidereal astronomy, is well known.¹ Nevertheless, recent work in the history of pedagogy, and in particular recent analysis of the work carried out by technicians and assistants, suggests new ways of understanding the claim that William Herschel was self-taught in astronomy.

Eighteenth-century practitioners of science such as the instrument maker James Ferguson, and members of the Lunar Society such as James Watt are, like Herschel, often described as self-taught.² In this paper I question what such claims meant in practice by looking in detail at the way in which William Herschel used resources at his disposal to become an accomplished practitioner in several different fields.

The special edition of *Notes and Records* on 'Technicians' (volume 62, part 1; 2008) has revealed a rich hidden world behind each practitioner of science. In Hannah Gay's article, for example, she identifies roles not only for collaborators and assistants but also for all those on the periphery: the tradesmen, technicians and outside contractors.³ A similar story of hidden contributors can be built around education. Already, some research has uncovered the complex processes involved in becoming a practitioner of science. The historians of scientific pedagogy Andrew Warwick and David Kaiser have shown some of the ways in which nineteenth-century and twentieth-century scientists and engineers were trained.

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Included in their analysis is the importance of tacit knowledge gained through immersion in the scientific community.⁴ That work, however, focused on formal training institutions and more specifically on university education.

In the eighteenth century a university education was much less common and by no means the only route to becoming an active member of the scientific elite. Alternative resources were available for studying and participating in science, including books, journals, lectures and societies.⁵ This 'marketplace' for science has been the subject of several articles and monographs, but the emphasis in those studies was on science for public consumption rather than as a resource for training aspiring natural philosophers.⁶ Using the example of William Herschel I show how these resources could have been, and indeed were, used to fashion the education of a future astronomer, natural philosopher and instrument maker.

LEARNING HOW TO LEARN

William Herschel gave several accounts of his childhood after his 1781 discovery of Uranus; he also kept a 'memorandum of his life'. In addition, his sister Caroline gave various accounts of her and her brother's lives, including their childhood together. From these records a picture emerges of a family conditioned to understand education as above all a means of social advancement. However, it was also a training that taught William how expertise is gained.

William Herschel and his siblings grew up in Hanover. Although there are no extant records of their family finances, Caroline's accounts cite several incidents that suggest they were not well off. They moved house frequently for financial reasons, often sharing with other families. She and her mother made the family's clothes, bed linen, meals and so on, and took in sewing to supplement the family income. At the same time she recorded her parents' refusal to allow her to train to become a lady's maid, a fact that suggests a concern with appearances and status.

Their father, Isaac, had avoided following his own father into gardening by using education (learning music) to raise his status and change his opportunities. He became an army musician, for the Hanoverian Guards, but he had higher ambitions for his children. Caroline recalled that their father's greatest hope was to 'see his children arrive at that eminence in this his favourite science [music], which he himself had not had the opportunity or time to attain.'⁷ According to William it was 'my father's greatest attachment to music [which] determined him to endeavour to make all his sons complete Musicians.'⁸

Isaac's ambition for his children meant that he taught music to his sons, Jacob, William, Alexander and Dietrich. William was taught 'to play on the violin as soon as I was able to hold a small one made on purpose for me.' When Isaac was at home he gave the boys lessons. When he was away (which was often and for long periods) Anna, their mother, ensured they practised. This arrangement taught William not merely how to play but also how to acquire expertise, and he soon realized that long intense periods of repetitive practice were essential. Aged 14 years, after an audition, William became a musician in the Hanoverian Guards.

Alongside music practice, William and his siblings went to the local garrison school to study 'basic literacy, arithmetic and religion'.⁹ Towards the end of his schooling, William took additional private lessons in French. In some accounts he claimed that his father

instigated and paid for the lessons to improve his prospects as a musician; in others of emphasized his own agency in the process.¹⁰ Either way, the lessons were encouraged. They were not useful for someone aiming at the status of army musician, but they were essential for an aspiring musician at Court, where French opera and singing lessons were popular.

Philosophy and instrument making were similarly non-vocational lessons encouraged in this family. William stated that it was his French teacher who encouraged ‘the taste he found in his pupil for the study of philosophy, especially logic, ethics and metaphysics which were his own favourite pursuits.’¹¹ According to Caroline these philosophical discussions were also encouraged at home, where their older brother and father often joined in. As Caroline (then aged 6 years) remembered: ‘the names of Leibnitz, Newton and Euler’¹² were often quoted.

Caroline also mentioned activities concerned with instrument making several times in her description of family life, referring to William’s ‘self constructed Globes &c &c’¹³. Elsewhere she wrote of their brother Alexander, who ‘often sat by us and amused himself with making all sorts of things on pasteboard, or contriving how to make a twelve-hour cuckoo clock go a week.’¹⁴ This occupation was by no means unusual. James Ferguson, James Watt, Alexander Cummings and David Rittenhouse all later recalled having pursued instrument making as a hobby in childhood.¹⁵ Like Herschel, they all developed this hobby professionally as adults, a fact that helps to explain the inclusion of these reminiscences in their biographical notes.

All three subjects—French, philosophy and instrument making—were learned with the help and encouragement of teachers and family. They were valued in this family primarily because learning and education were seen as a means of facilitating social mobility. French was useful for teaching French opera, philosophy came from the interests of a teacher, and instrument making was perhaps just popular at the time. It may also have come out of skills they acquired repairing their own musical instruments.

William Herschel’s childhood, as seen through diaries and reminiscences, demonstrates the care that must be taken with terms such as self-taught and autodidact. This was no formal training designed to make him a practitioner of science; nevertheless he was being trained—in part at home—to become a professional musician. Through family and teachers he was taught to value education; he was also shown how to learn and gain expertise. It is in these lessons that we begin to see what he meant by self-taught. That is, that his agency in the process came about not through isolated study but through his choices and active pursuit of tutors.

PHILOSOPHY AND MUSIC AND PHILOMATHS

One of the reasons I show here why William first began studying natural philosophy was that it was an interest of some of the employers he served as a musician. Natural philosophy was regarded as a polite topic of conversation in England throughout the eighteenth century.¹⁶ Lawrence Klein has shown how Thomas Parsons studied polite topics to win over clients in his work as a maker and seller of luxury goods, and argued that this led Parsons to engage in a programme of self-education.¹⁷ As a musician, William was in a similar position, serving polite society as an employee, looking for exploitable areas of shared interest. Like Parsons, he found this in natural philosophy.

William and his brother Jacob left Hanover for England in 1757 towards the beginning of the Seven Years' War. William stayed to find work as a musician. Jacob returned home to a post in the Hanoverian Court Orchestra.¹⁸ There was a growing market for musicians in mid-eighteenth-century England as musical audiences expanded, no longer confined to Court circles. As Cyril Ehrlich has observed, this created a new breed of musician: a jobbing musician, playing concerts and at country homes and giving private music lessons rather than relying on a patron. It was a profession dominated by foreigners, mainly Italian and German, and was one of the few areas that allowed its members to mix in socially elevated circles.¹⁹ Like Thomas Parsons, musicians such as Herschel were dependent on members of this elevated class for work, meaning that there were sound professional reasons for learning their rules of etiquette.

Although William makes no mention of how he learned the proper way to conduct himself within this polite society, his later account of training Caroline offers some clues. After William had finished her technical education, teaching her how to sing, how to read music, and so on, he employed a dance teacher to teach her deportment and sent her to London with a fashionable lady friend, Mrs Colebrook.²⁰ In both cases the intention was to teach her presentation skills: how to hold herself and how to act among his musical clients. As a performer and jobbing musician, William needed to learn similar skills.

William initially found work in a militia band run by Lord Darlington, but soon he became a jobbing musician, playing concerts and giving music lessons in country homes across the northeast of England. In William's letters to his brother Jacob he expressed frustration with this role and its lack of security and regular income. When the possibility of a post in Edinburgh came up in 1761, William went to the audition. There he was introduced to and had dinner with the metaphysician David Hume.

When William had first arrived in England he had read the philosopher John Locke's *Essay Concerning Human Understanding*.²¹ 'I applied myself to learn the English language and soon was enabled to read Locke on the Human Understanding.'²² Locke's book described the process of learning and emphasized that it came from practice and repetition. This description, as we have seen, resonated with the way in which William had learned music. After his meeting with Hume, William began to read other philosophical works.

In the early 1760s William read, among others, Leibniz's *Theodicee*, William King's *An Essay on the Origin of Evil* and Robert Smith's *Harmonics, or the philosophy of musical sounds*.²³ Although his correspondence gives us the titles he was reading, it does not explain how he came to acquire those books. By the second half of the eighteenth century a common way of accessing books, more popular certainly than buying them from a bookseller, was to rent them from circulating libraries.²⁴ This would make sense for William at this time, given that he had no permanent base (a point he complained about to his brother) and an uncertain income. By considering where he got his books from, we also get an indication of how he came to choose his titles. Libraries, and the booksellers and agents running them, could recommend titles; they also had catalogues to browse and had carefully organized display shelves.

After this reading, in 1764 William began to write his own *Treatise on Music*.²⁵ This treatise was never published and has never previously been discussed by historians, but in terms of his transformation from musician to natural philosopher it provides a useful insight. This treatise was the first piece of work that William produced that attempted to engage in any form of philosophical writing.

The intended content (the contents list is complete but not the extant manuscript) suggests that this treatise was written for his music students. There are, however, aspects of the work that show an attempt to integrate music, with his developing interests in philosophy. Smith's *Harmonics* is the only book cited in the treatise, cited once to tell readers where they might learn more on the mathematics of harmonics, and again a few pages later on: 'For a mathematical Division and account of these intervals see Dr Smiths Harmonics, Art: 1. Sect. II.'²⁶ However, although he cited Smith, he also argued against Smith's attempt to reduce music to mathematical rules:

But let us even suppose (which wants confirmation) that the degrees of pleasure arising from musical sounds answer'd perfectly the order of the simplicity of the ratios . . . [still we do not know] why those ratios were agreeable and so forth . . . Music is a kind of natural philosophy where we reason best from Experience, and matters of fact are often the best and clearest arguments we can bring.²⁷

Here, his analysis has elements of Locke, such as his claim that the best way to appreciate music is from experience. Mostly, however, this passage shows William's unwillingness to reduce music to mathematics.

William's correspondence with his brother over his *Treatise on Music* suggests that he was working on it around 1764. Up to this point, besides his meeting with Hume, he mentioned discussing philosophy with no one other than his brother. Then, in 1766, William made several references to people, books and activities suggesting he had come into contact with a group known to contemporaries as philomaths.

Philomaths were the readers and contributors to journals such as the *Ladies' Diary* and the *Gentleman's Diary*. These journals, as Jon Topham has shown, came as a response to changes in the publishing trade, but also through the enthusiasm of their editors to collate and disseminate new knowledge.²⁸ These philomaths attended lectures and read books, and some owned telescopes with which they might hunt for comets. Shelley Costa has described the readership of the *Ladies' Diary* in the mid eighteenth century as typically those from the leisured classes, with the time to ponder mathematical puzzles, and 'also the luxury of using written correspondence as entertainment'.²⁹ Olaf Pedersen looked at the *Gentleman's Diary* readership, concluding that they comprised mainly school teachers and 'leisured country gentlemen'.³⁰

Ruth and Peter Wallis's analysis of eighteenth-century philomaths and philomath culture reveals not only the range of participants but also their broad interests. John Draper's print (figure 1) gives an indication of the types of subject considered in the eighteenth century to be philomathematical.³¹

The Wallises' description is even more wide-ranging than this diagram suggests, because the range of activities covered includes music and instrument making. William's journey through these different interests and specialisms places him very definitely in the philomath tradition. The Wallises' description gives no indication of how homogeneous the philomaths were as a group. William Herschel's example suggests that some, if not all, philomaths were selective. As we shall see, he moved slowly from one area to another, hesitant at each stage as to how much he could claim regarding his expertise in each new field.

In 1766 William formally acknowledged his engagement with the philomath community and their role in shaping his reading habits. His very first reference to the group was on 1 January:

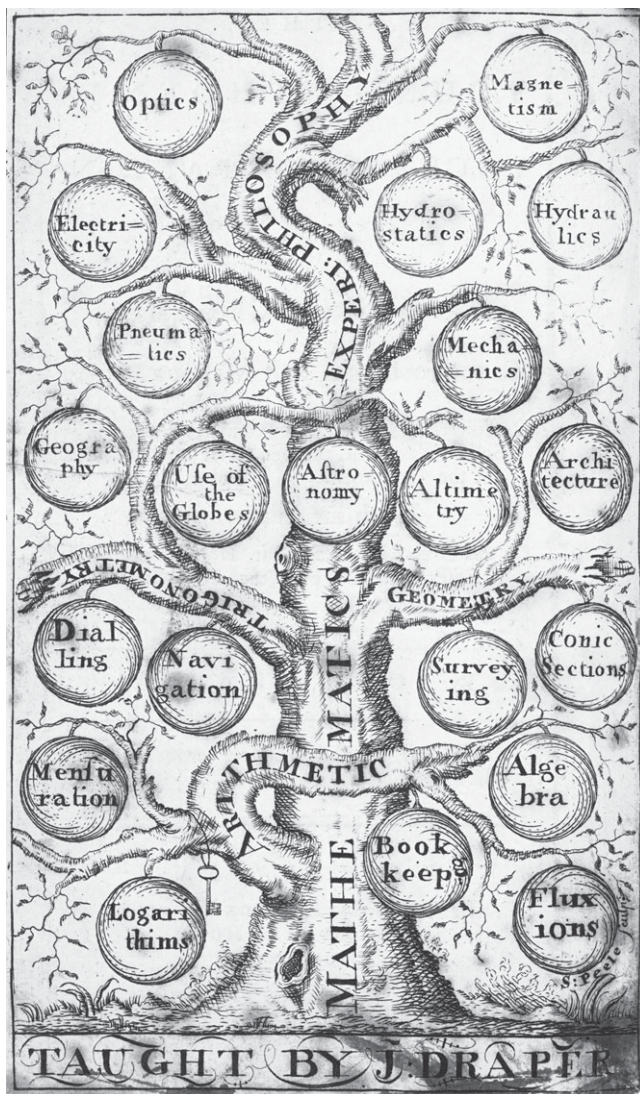


Figure 1. Frontispiece to J. Draper, *Young Students' Pocket Companion* (1772). (Copyright © The British Museum.)

1766, Jan 1. Wheatley [near County Durham]. This was the country seat of Sir Bryan Cook, where every fortnight I used to spend two or three days. Sir Bryan played the violin and some of his relations generally came from Doncaster to make up morning concerts

Feb. 19. Wheatley. Observation of Venus.³²

Bryan Cook, as far as can be deduced, was a philomath. Little is known of him, yet William's reference here suggests that he had some interest in astronomy that he was keen to share.

Two weeks later William described receiving a letter from ‘Mr Grey, a philosophical Gentleman with whom I have corresponded. He was a brother of Sir Henry Grey of Northumberland and lived in Newcastle.’³³ Again, little is known of Mr Grey, though significantly William describes him as ‘a philosophical gentleman’, making Grey a possible source for William’s knowledge of whom and what to read. In both cases, Cook and Grey, these were highly significant social and intellectual connections made through music that helped William to start to shape his education in philosophy and astronomy.

Some time later in 1766 he described an audition:

I was a candidate for the place of organist, which by the interest of the Messrs Bates and many musical families I attended, I had great hopes to obtain. About this time I was an inhabitant of Halifax. My leisure time was employed in reading mathematical books such as the works of Emerson, Maclaurin, Hodgson, Dr Smith’s Harmonics, &c. This happened to be noticed by one of the Messrs Bates who told his brother: ‘Mr. Herschel reads Fluxions!’³⁴

These books are precisely those that were widely read by eighteenth-century philomaths, and they show a notable shift in William’s established reading patterns.³⁵ The books he discussed with his brother in the 1750s and early 1760s were famous books by well-known philosophers. They were books taking a philosophical look at subjects that William knew, such as Smith’s book on harmonics. The books he now perused were more technically demanding titles by less famous authors, and were specifically on fluxions. They show an attempt to master a new subject that might impress his social superiors rather than provide new angles on subjects already known.

The books that William now began to scrutinize were written by schoolteachers (Emerson and Hodgson) and professors (Maclaurin and Smith). Hodgson stated his audience to be ‘principally young Beginners’; Emerson’s writing style, and the context of his other books (on mechanics and on trigonometry), suggest a similar beginner/schoolteacher audience. Maclaurin’s is slightly different. His preface dwelt on the inadequacy of the existing literature on fluxions, stating that his book was written as a response. According to Niccolo Guicciardini, the market for these books was steadily growing in the eighteenth century, reaching its peak mid-century. William was therefore taking an interest just as these books were at the height of their popularity.

As the above quotation suggests, William was not only interested in learning fluxions, he was also keen for his educational pursuits to be witnessed. One of the ‘Messrs Bates’ mentioned has been identified as Joah Bates (1740–99), a musician, civil servant and key player in the organization of public music events in his home town of Halifax.³⁶ For the Bates brothers to know that William ‘reads fluxions’, William must have made this information public by talking of or demonstrating his reading.

William was hardly alone in using philomath culture as a stepping stone to social and professional success. Although the term philomath is rarely used today as a description of a historical character, the journals they contributed to, the *Ladies’ Diary* and the *Gentleman’s Diary* in particular, crop up with remarkable regularity in the biographies of minor figures engaged in eighteenth-century scientific life. The silk weaver and amateur astronomer James Six, the self-taught mathematician John Dawson, and the clergyman and man of science George Walker, for example, were all contributors. William Wales went from contributor to the *Ladies’ Diary* to assistant at the Royal Observatory, Greenwich, without any apparent formal training and certainly without a university education.³⁷

William read books written for philomaths and advertised his understanding of these works. Further evidence of his involvement with philomath culture can be found 14 years later in the *Ladies' Diary* for 1780, in which William's solution to a problem incorporating both mathematics and music was published.³⁸ The *Ladies' Diary* worked by setting problems in one edition and printing all the correct solutions in the next, complete with workings and a list of names of all who sent in correct answers by that method.³⁹ William's submitted answer was the first public demonstration of his abilities to a purely philosophical (as opposed to musical) audience. That he selected a problem incorporating both mathematics and music demonstrates his caution in claiming too much for his abilities. The problem asked for the number of vibrations of a musical string when the length, tension and weight are given, and a small given weight is 'fastened to its middle and vibrates with it.'⁴⁰ William's entry cautiously acknowledged that his answer was 'not to be considered mathematically true, but as a practical solution approaching near the truth.'⁴¹ Whereas to other musicians, in the context of an audition or music lesson, he presented himself as a master of fluxions, to other philomaths he instead promoted his authority as a musician.

These early formative years of William's life, when he was first introduced to natural philosophy and then spent years studying, have previously been ignored in all secondary literature. It is significant, however, in that it shows the resources available and how and why they may have been accessed. As a jobbing musician William had discovered a shared interest in natural philosophy with several of his employers. With that knowledge he set about developing his expertise, making himself their equal, by creating an education from available literature and through informal networks. His transition from music to philosophy was slow and cautious, and he took care to tailor his claims regarding expertise to his audience.

ASSEMBLING HIS TEAM

A crucial turning point in Herschel's career came when he decided to make telescopes. Richard Holmes has already commented on the importance of Caroline's arrival in Bath in enabling William to take up this new hobby.⁴² Equally important, I show here, was the arrival of their brother Alexander, and indeed it is only by recognizing the range of contributors to the Herschel project that a satisfactory role for Caroline can be understood. Although Caroline is always mentioned in accounts of William Herschel's life and work, there is some debate regarding the exact nature of her contribution and why it might be considered significant to the history of science. Michael Hoskin suggests she was a 'mere' assistant and less talented than her brother. Others, meanwhile, have chosen to characterize her as an ambitious pioneer.⁴³ Here I introduce Caroline as part of a team that William put together. In this context, William and Caroline are presented not in competition but as part of a larger collective who made William's telescope building and observing plans possible.

The word 'team' used in this sense is not a contemporary term. The Herschels, if they talked collectively about the people involved in their astronomy and instrument making activities at all, would have used family, household, or, if pressed to include the various outside contractors, workmen. They did not describe themselves as equal participants. Caroline in particular always emphasized her subordinate role, but that does not mean that

we should accept that hierarchy uncritically. I have used the word ‘team’ here to allow all the participants in the work to be acknowledged.

In 1770 William’s younger brother Alexander arrived in Bath, hoping to find work as a musician. Alexander was a dedicated and skilful mechanic. When the brother-in-law of William’s son John went through William’s correspondence, he found ‘some curious ones of his brother Alex all confined to the subject of mechanics.’⁴⁴ The letters lacked the social niceties normally found in correspondence between siblings and were instead purely functional and technical in tone. When pushed further, John gave the following anecdote about his uncle Alexander:

He never moved away from his own home, except to pay a yearly visit to his brother’s [i.e. William’s] family and then invariably came accompanied by his turning lathe and other implements, and getting himself & them established the moment of his arrival, in the workshop (now H’s observatory) scarcely left that apartment during the whole period of his stay. . . . He used to go away after his stated week of visitation had expired having scarcely seen his friends all the time, but declaring himself quite delighted with their society.⁴⁵

Letters between the brothers suggest that, while in Bath, William relied on the technical skills of Alexander.⁴⁶ Collectively, this archival material suggests that Alexander was not sociable but instead single-minded in his attention to technical and mechanical detail. In terms of learning how to build state-of-the-art telescopes, this was an extraordinary asset.

A second important factor was the arrival of Caroline in 1772, relieving William of many time-consuming activities including supervising household staff and, as her English and music improved, copying out musical scores and teaching the choir.⁴⁷ A third factor was the opportunity presented by a local man giving up his hobby making mirrors. William makes no reference to this man’s identity except to say that he lived in Bath and would sell him his tools and give him lessons.⁴⁸

William’s tutoring under this local mirror-maker did not, according to his own testimony, last long: ‘going to work with these tools I found no difficulty to do in a few days all what he could show me, his knowledge indeed being very confined.’⁴⁹ William then continued in September 1773 ‘with the assistance of Dr Smith’s popular treatise.’⁵⁰ In the same year he bought and studied James Ferguson’s *Astronomy*,⁵¹ Emerson’s *Trigonometry*,⁵² Emerson’s *Optics*⁵³ and, around the same time, Emerson’s *Mechanics*.⁵⁴ Both Smith and Emerson were authors he had read before. James Ferguson wrote for a similar audience, and, as Anthony Turner has previously observed, was lecturing in Bath at around this time.⁵⁵

Smith and Emerson gave clearly written advice for constructing different kinds of telescope. Smith, as Michael Hoskin and Reginald Jones have already shown (figure 2), provided step-by-step instructions on how to build a telescope very similar to the 7-foot reflector William eventually perfected (figure 3).⁵⁶ Emerson meanwhile provided more general mathematical tools with which to solve problems when varying the design of the telescope.

Although William is always named as the maker of this and all his later telescopes, each one was a team effort. William made, cast and polished the primary mirror. In the context of the instrument-making industry, this alone qualified him to be the named maker of the telescope.⁵⁷ However, Alexander made the eyepieces and micrometers, and a cabinet maker was called upon to build the wooden tube and stand. In fact, Caroline’s autobiographies suggest that even the mirrors were a team effort, with Caroline sometimes helping to make the moulds (out of manure and straw).⁵⁸ On another occasion, William

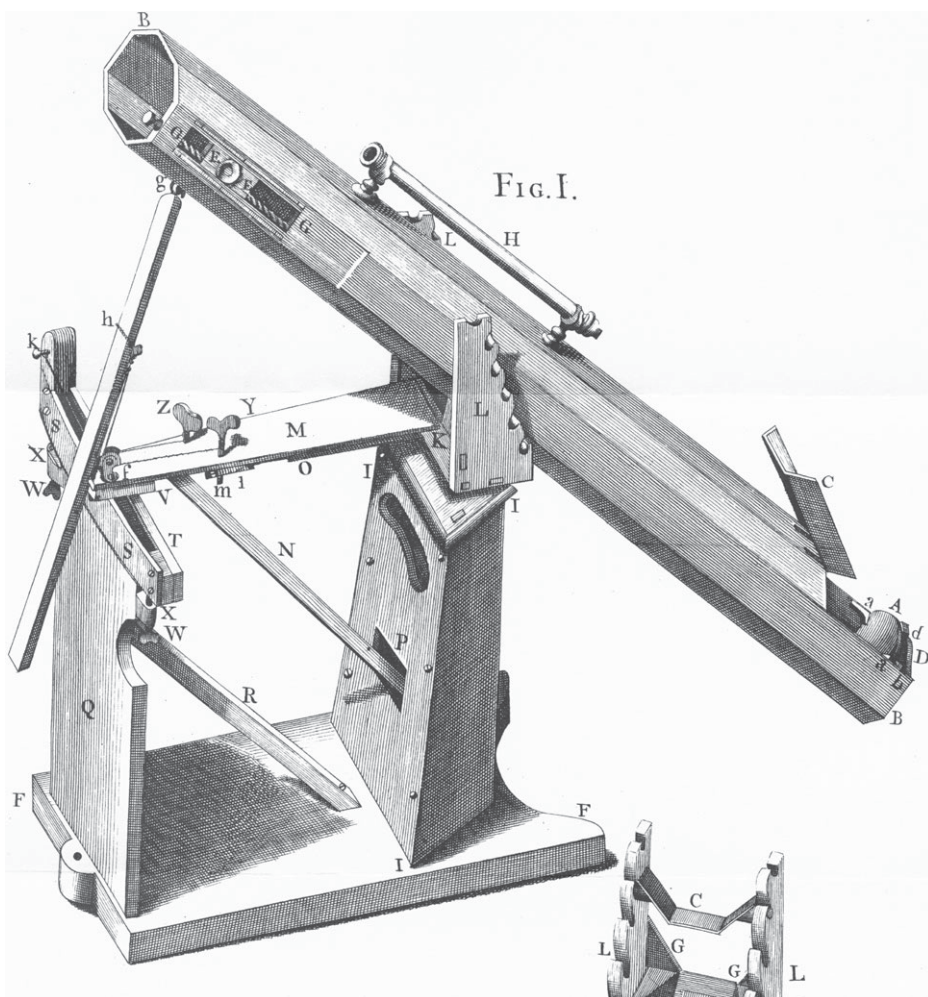


Figure 2. Hadley telescope from Robert Smith, *A Compleat System of Opticks* (1738), p. 376. (Copyright © The Royal Society.)

and Alexander together were noted as having been present when a mould broke, causing molten metal to damage the kitchen floor.

Besides providing a basic telescope design, Smith's book was also useful, as Hoskin and Schaffer have discussed, in providing William with descriptions of what he should be able to see through the telescope.⁵⁹ A further use not previously considered is that Smith's book may have offered William a guide in how 'to practice seeing'.⁶⁰

In addition to its section on instrument making, on mathematics and on telescopic discoveries, Smith's *Opticks* contained a section entitled 'A Popular Treatise' within which was the chapter 'Concerning our ideas acquired by sight'.⁶¹ This chapter's arguments were framed within the context of Locke's *Essay Concerning Human Understanding* and his views on learned knowledge. The chapter went on to describe William Cheselden's work on cataracts. Cheselden was a famous surgeon from the early



Figure 3. A Herschel 7-foot reflector. (Object number AST0960, image ID F5601-001; copyright © The National Maritime Museum, London.) (Online version in colour.)

eighteenth century. His work on cataracts involved their surgical removal, followed by intensive training in which the patient was taught to see again (or for the first time). This showed that sight was not purely a function of the eye, but also of the brain learning to interpret what was seen. William had learnt music through concentrated repetitive solitary practice from an early age and here, described in Smith, presented as an application of Locke's ideas, was that same practice applied to sight. William applied this technique to his own sight, describing the process to his friend Alexander Aubert, a businessman and astronomer with his own observatory:

When you want to practice seeing (for believe me Sir,—to use a musical phrase—you must not expect to see at sight or a livre ouvert) apply a power something higher than what you can see well with, and go on increasing it after you have used it some time.⁶²

By practising observing as he had practised music, William became an excellent observer. His instrument-making skills also improved as he practised and perfected the art of mirror making, experimenting with different alloy compositions and polishing techniques. Then in 1778 he read a paper on mirror making in *Philosophical Transactions of the Royal Society*. The paper was by John Mudge, a physician by profession, and a brother of the famous clockmaker; it described a technique that had won Mudge the Royal Society's Copley Medal. William tried out the technique described and decided that his own method produced a better mirror.⁶³ This observation gave him renewed confidence in his abilities.

Although membership of the Royal Society at this time included a large percentage of time-servers, rich gentlemen with no particular interest or talent for science, its Copley Medal was nonetheless a prestigious prize, awarded to those regarded as having made an outstanding achievement in science. If Mudge's technique was regarded as outstanding, and William's was better, that surely must be evidence that his efforts had paid off. When William had sent in his solution to *Ladies' Diary*, he had explained his right to do so in terms of the question's musical content, and his expertise in that field. After his reading of Mudge, William began a new tack: instead of claiming authority through his musical expertise, he would now claim it through the precision and quality of his astronomical instruments.

BATH PHILOSOPHICAL SOCIETY

In 1779 William began to get to know members of the Bath Philosophical Society, one of several regional philosophical societies to emerge in the late eighteenth century. These were societies in which the university-educated and the self-taught alike could come together to discuss the latest scientific thinking, and develop those ideas through experiment and discussion. They were also often a place for gaining access to otherwise prohibitively expensive literature through the formation of society libraries.⁶⁴

According to Klein, the Bath Philosophical Society was established in part to aid social mobility. The society's president, Edmund Rack, was a weaver's son, who worked as a draper while cultivating literary and intellectual friendships and interests. In 1777 he set up the Bath Agricultural Society. Two years later he joined with Thomas Curtis, a governor of the Bath General Hospital, to form the Bath Philosophical Society. This society was successfully designed to attract both gentry and the self-made such as Rack, Parsons and Herschel. Like the Agricultural Society, this society had a strong bias in favour of agricultural development and natural history, but it also encompassed more diverse scientific and literary interests.⁶⁵

By the end of 1779 William had successfully tested the quality of his telescopes and, as we have seen, recognized the value of public demonstrations of learning. With this in mind, he took his telescope into the street to observe the Moon:

I brought my seven feet reflector into the street, and directed it to the object of my observations. Whilst I was looking into the telescope, a gentleman coming by the place where I was stationed stopped to look at the instrument. When I took my eye off the telescope he very politely asked if he might be permitted to look in, and this being immediately conceded, he expressed great satisfaction at the view. Next morning the gentleman, who proved to be Dr Watson, jun. (now Sir William), called at my house to thank me for my civility in showing him the moon, and told me that there was a Literary Society then forming at Bath, and invited me to become a member of it, to which I readily consented.⁶⁶

This 'literary society' was the Bath Philosophical Society. Dr Watson was a member of this society and of the Royal Society; he was also a physician with an interest in botany and mineralogy. William was keen to make a good impression on both Watson and the society as a whole.

William chose to give his first paper not on mathematics, astronomy or instrument making, but on natural history.⁶⁷ This choice, so outside William's normal areas of

interest and research, suggests an eagerness to please his hosts. This first paper described his observations over a series of days of a branch of coralline and the apparatus he used, giving particular attention to the microscope's magnifying power.⁶⁸ In his concluding remarks he made a throw-away reference to Leibniz, suggesting that if certain things were true 'it would almost look something like an instance of Leibniz's pre-establish'd Harmony.' In this one paper he introduced himself to the society and attempted to grab their attention with a topic from their, rather than his, field of expertise. At the same time, he tried to present himself as an expert on instrumentation, well informed in natural philosophy.

Further evidence of William's wish to ingratiate himself with the Bath Philosophical Society's members can be found in his collaboration with Curtis. This is the only instance of William's working on a project with anyone outside his immediate family, and it demonstrates his enthusiasm for fully engaging with the society. The papers themselves—all short descriptions of electrical experiments performed—came out of discussions after William's paper on Joseph Priestley's *History of Vision*.⁶⁹

In between his papers on natural history and electricity William began to report on observations made with his telescopes.⁷⁰ Two of these papers—one on a star in Collo Ceti, the other on lunar mountains—were later read to the Royal Society. The first of these was in essence an edited transcript of two years from his observing journal for Collo Ceti. The second was more ambitious. He began by explaining that his reason for observing the Moon was to repeat the observations of 'Galileo, Hevelius, Kircher' as 'their instruments were far from being arrived to that degree of perfection we now have obtained.' Like his first paper, his arguments and descriptions surrounding his observations centred on the quality of his apparatus and his breadth of reading.

In William's progression of papers to the Bath Philosophical Society there is a gradual shift in how he presented himself as he absorbed the culture, learning how ideas must be presented. His early papers simply flattered his host, while describing what he had done and seen. Gradually, however, he learned how to use his papers to present ideas, not just descriptions, and the correct way to incorporate references to his reading and the superiority of his telescopes. When he came to discover the planet Uranus in 1781, his involvement with the society meant he knew just how to word his announcement and whom to tell.

CALCULUS VERSUS FLUXIONS

William's self-education had taught him to observe, to build telescopes, to write papers and to present himself and his work in a way that would get him noticed. However, this education had its limits. It was, as he was to find out, a very English education.

In 1781 Nevil Maskelyne informed the French astronomer Charles Messier of William's discovery of a new planet.⁷¹ Calculations on the planet's orbit followed, performed by Messier, Lalande, Méchain and Dagelet, and were then communicated to William by Joseph Jérôme Lefrançois de Lalande in May 1782.⁷² This was the first letter in a long-running—and previously unexamined—correspondence. Through this correspondence, we see the limits of William Herschel's education.

France and England were at war for much of the eighteenth century, establishing the boundaries of their new empires, and this had repercussions for the transmission of scientific and mathematical knowledge. The various attempts during the eighteenth century to introduce ideas from one nation to the other suggest that scientific activities in each country

followed separate trajectories. The dispute between Maupertuis and Cassini during the 1730s over the shape of the Earth was in part an argument over English science, mathematics and instrumentation versus French alternatives.⁷³ Émilie du Châtelet's reputation was built on bringing Newton's ideas from England to France.⁷⁴ The *Ladies' Diary* and *Gentleman's Diary* were originally produced in part to introduce developments in French mathematics to the English. In each case, attempts were made to bridge a perceived gap between the science, philosophy and mathematics of the two countries.

Over the course of the eighteenth century, each country had developed its mathematics separately, with English fluxions becoming increasingly empirical, and Continental calculus increasingly abstract.⁷⁵ In England the work of Newton had evolved through the work of people such as Taylor, Maclaurin and Simpson. In contrast, in France, mathematics was moving forward through the work of d'Alembert, Lagrange and Laplace. For those engaged in mathematical study, this nationalistic divide meant that expertise could generally only be achieved in the mathematics of one country or the other. As Olaf Pedersen has observed, the sources that William was using to learn fluxions were loyal to the English side, completely ignoring French calculus.⁷⁶ William had studied fluxions, but he slowly discovered that this was of limited use in understanding the work of his French colleagues.

Lalande's first letter contained results of calculations performed on William's new planet, followed by a request for information about both William's life and his telescopes. William's reply began politely. He admired Lalande and thanked him for the results. In reply to his questions, he told him he had been born in Hanover and 'brought up to Music; my leisure hours were generally devoted to mathematics and other studies.' In other words, he had always been interested in mathematics. Lalande had expressed an interest in his telescopes; William presented himself not as an instrument maker but as a mathematician and philosopher.

For a time, the correspondence between William and Lalande followed a pattern. Lalande would relate the results of new calculations and introduce natural philosophers from across Europe. William, meanwhile, would discuss work that he was about to have published. Then, in the summer of 1788, not long after William had married Mary Pitt, Lalande visited England. William's marriage to this rich widow had been the source of some unflattering gossip. Although he may have resented these slights, it was true that Mary had introduced a change of pace to the family. Money was no longer a concern. Family holidays were taken, a point that Watson observed, which made for a more measured, less fraught approach to working life. Lalande's visit, then, must be seen in this light. Just as Caroline's arrival gave William the freedom to begin telescope building, his marriage to Mary allowed him time to begin to understand French mathematics.

Lalande's visit in 1788 marked a turning point in their correspondence: the letters that followed were filled with explanations and mathematical examples.⁷⁷ In one letter William asked for a paper to be shown to Jean-Baptiste-Joseph Delambre. Lalande's reply related Delambre's corrections line by line, ending that 'if you had sent observations in more detail to De Lambre more rigorous determinations would have been attempted.'⁷⁸ William's response was defensive, and apologetic. He was embarrassed at having made the mistakes and was quick to explain them away, telling him:

I have so little leisure for practice that it would be no wonder, on account of the multiplicity of things that take up my time, and continually disturb my thoughts, when I am calculating, if I had made many more blunders than I have made⁷⁹

William's mathematical abilities had reached their limits, and he was embarrassed. Nevertheless he stayed friends with Lalande and continued to build contacts across the Channel. He passed papers to them, and they in turn sent back papers and books, making his library unusually diverse for an English philosopher. William's education was made possible by his cultivation of useful, intellectually generous contacts, and by his ability to use other people and resources in his life to free up his time sufficiently to study and develop expertise. His contact with French mathematicians showed the limits of this process. Their mathematics was too different. Although he maintained an interest in French mathematics and astronomy, he decided to leave its mastery to his son, whose education in this area he would nurture and encourage.⁸⁰

CONCLUSION

William Herschel was remarkable in coming to possess a serious expertise in practical astronomy from a background in music. It was not, however, uncommon for eighteenth-century children to make scientific instruments as a hobby. Nor was it unusual for those in professions that engaged with the leisured classes—as traders or tutors—to regard natural philosophy as a useful tool in developing their professional reputations. William's use of philomath contacts and philomath literature followed similar patterns to those of many of his contemporaries. He also, like Thomas Parsons, Edward Rack, John Dawson and George Walker, found in his local philosophical society a means of mixing with and learning from individuals who could help him develop as a natural philosopher and ultimately become a Fellow of the Royal Society.

Scientific education in eighteenth-century England involved participation in several informal and ever-changing groups. These subsets of the scientific world—the philomaths, the lecturer/instrument makers, the philosophical societies and the Royal Society—all had different ways of engaging with scientific knowledge, but, as Herschel's example has shown, they were interconnected. It was possible to move between groups and, in doing so, to learn not just the content and tacit knowledge involved in becoming a practitioner of science, but also how to construct and present an appropriate image.

A current trend in the history of science has been to focus on historical actors outside the world of elites. Herschel's example shows this to be an artificial divide in the eighteenth century. Academicians wrote books read by philomaths; members of the Royal Society learned their science from travelling lecturers and regional philosophical societies. Although some men of science received a university education, many did not. In both cases, much of their scientific education came through the kinds of network described above.

The story of William Herschel's education demonstrates the way in which these networks and resources were used, and how one might progress through them, rising through social as well as scientific ranks, to reach a position of prestige and authority. William was not simply a passive recipient of this education. He actively sought out networks, reading material and tutors, he acted on advice, and he applied his learning in imaginative ways. In that sense he was self-taught.

At the same time, William's story also shows us the range of people involved in enabling his education. Although in a sense he was self-taught, he cannot take sole credit for his education. His education was made possible by mentors and tutors; he was also helped by his siblings, local craftsmen and his wife, who collectively freed up his time, shared his

workload and added skills to his scientific enterprise. Without this extensive team around him, William would have been able to achieve very little. William's story gives us a detailed glimpse of what was probably a common form of scientific education in eighteenth-century England. His encounter with French mathematics shows that it was a specifically English experience.

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NOTES

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