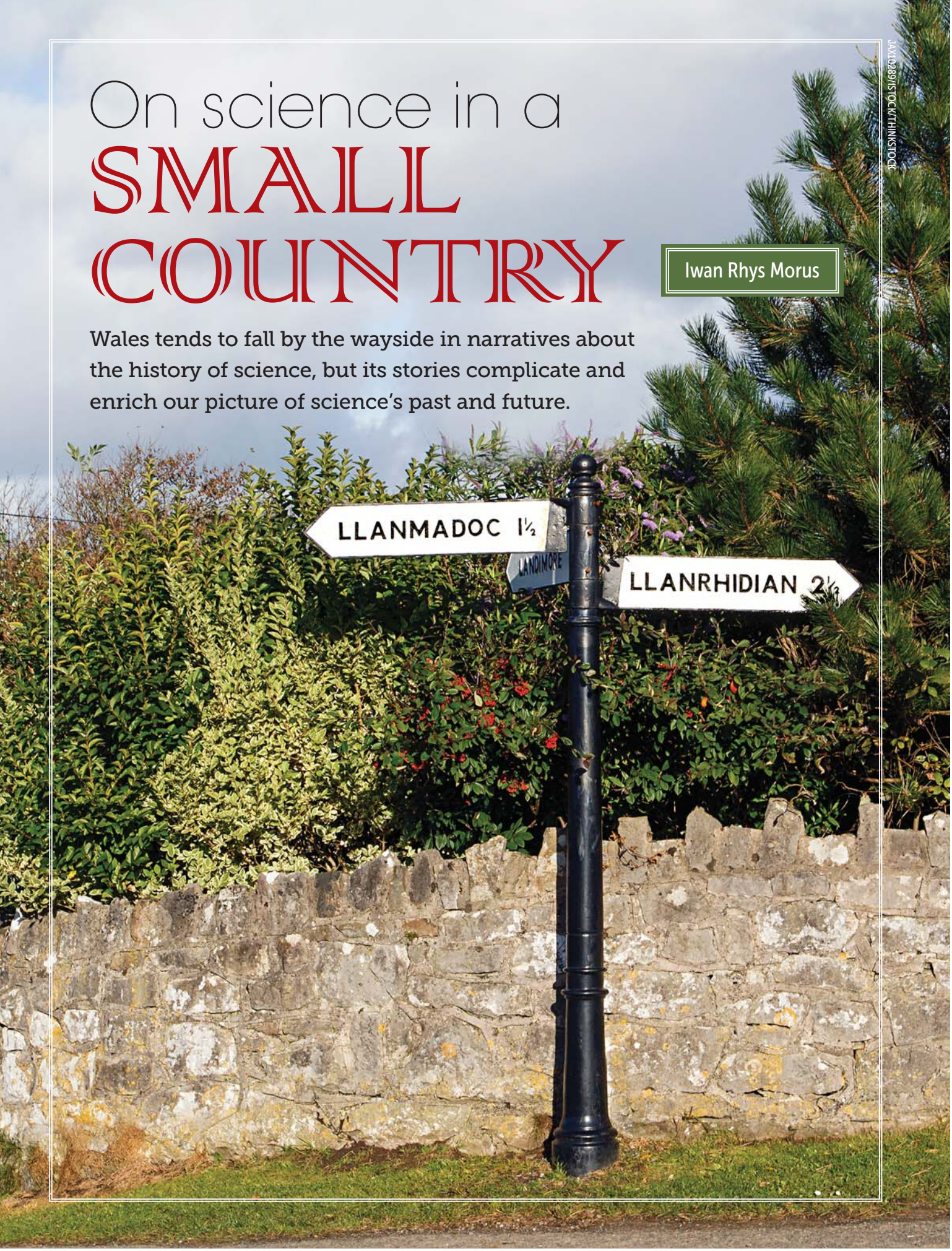
On science in a SMALL COUNTRY

Iwan Rhys Morus

Wales tends to fall by the wayside in narratives about the history of science, but its stories complicate and enrich our picture of science's past and future.



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Iwan Rhys Morus is a professor of history at Aberystwyth University in Ceredigion, Wales. His latest book is *William Robert Grove: Victorian Gentleman of Science* (2017).

In 1756 Welsh hymnist and religious reformer William Williams Pantycelyn composed an epic poem titled *Golwg ar deyrnas Crist* (*A Survey of Christ's Kingdom*). By any standards a remarkable piece of work, it consisted of an impressive 1367 verses, amounting to 5468 lines. Eight years later Pantycelyn published a revised edition of the poem (see figure 1), consisting then of 1366 verses.[1]

As the title suggests, what Pantycelyn offered his readers was a detailed account of God's creation and humanity's place in it. The poem is notable for its detail and in particular for its extended discussions of the latest scientific ideas about the nature of God's creation. The universe that Pantycelyn described was an unmistakably Newtonian one. In the second edition, published in 1764, Pantycelyn included extensive footnotes, expanding on the scientific ideas traced out in the body of the poem. Those footnotes were expressly intended, as Pantycelyn made clear in his preface, to explain the relevance of "y philosophyddiaeth bresennol" ("the latest philosophy") to the poem's broader religious message.

The presence of science in Pantycelyn's writings is significant—and goes rather against the grain of the conventional image of Welsh culture and history. Wales tends to be associated with religion and rugby, poetry and song. It breeds tenors, bards, and rugby players rather than scientists and engineers.

Historians of science have tended not to pay much attention to little countries like Wales, just as Welsh historians have paid little attention to science. Historians of science, when they study national context, tend to focus on the big, ambitious, and powerful nation-states. Plenty of histories cover US science or Soviet science, for instance. Much has been written about science in imperial Victorian Britain. Philosophers of science tend to hold that science belongs to no particular place—that its origins are irrelevant to its content.

Looking at science in a small country is a good way of getting at why place does matter. It matters because where science gets done and how scientific ideas circulate through culture are critical to the way people understand it. What science means to people and how people think about their own relationship with it depend in part on where science is seen to be done. If our view and focus are firmly fixed on the great names and on science's role in making powerful nations more powerful, we can easily miss the range of ways in which people understand science and what they think it means for them.

Pantycelyn's vision of science

As a small country on the western fringe of the British Isles, Wales has spent much of its history on the periphery of empires—Roman, Angevin, and British. Throughout that history, it has maintained its own distinct language and culture. Welsh, still spoken by about 20% of the population, was for most of the last millennium and a half the country's dominant language. There remains a continuous literary tradition in Welsh that has its origins in the first emergence of the language during the sixth century.

Histories of Wales tend to focus on its literary and religious identity and on its changing political landscape.[2] There is little room in such histories for looking at how science has shaped Welsh culture—or how Welsh culture has shaped science. That is an odd omission, since very little digging will uncover the pervasive role that science has played in the Welsh imagination and in developing and sustaining Welsh identity.

Pantycelyn's example makes the case. He is an important figure in Welsh history for several reasons.[3] He is mainly remembered now as a highly prolific author of hymns. During his lifetime, he wrote almost a thousand of them, including "Guide Me, O Thou Great Redeemer," still triumphantly belted out in the very secular atmosphere of Welsh rugby matches.

Born in 1717 to a reasonably prosperous farmer, Pantycelyn (see figure 2) originally intended to become a physician, but after undergoing a profound religious conversion around age 20, he decided to become a clergyman instead. He was a leader in the Methodist movement that swept through the Anglican church in Wales during the 18th century and that eventually led in 1811 to the Methodists separating from the Anglican church and ordaining their own ministers. Debarred from promotion in the church because of his Methodist proclivities, Pantycelyn scraped a precarious living instead as an itinerant preacher. He crisscrossed Wales on horseback, traveling from parish to parish to deliver his Methodist message.

As he rode, he read. It is clear that the books he devoured from the saddle must have included some scientific texts. Pantycelyn knew his science—and wanted his readers and listeners to know it too. Indeed, science was built into his religion and his religious sense of who he was. It offered him a way of

understanding God's creation that he wanted to share with his audience. In that respect it was important to Pantycelyn's efforts to forge a uniquely and identifiably Welsh religious identity.

Golwg ar deyrnas Crist opened with God's transfer of his creation to Christ's care and proceeded with a systematic description of the earthly kingdom that Christ inherited from his father. It concluded with Christ's return of creation to God's care at the end of time.

The natural philosophy that underpinned *Golwg ar deyrnas Crist* was remarkable in its breadth and detail. As Pantycelyn's footnotes show, the main source for his philosophical knowledge was *Astro-Theology*, written by English clergyman and natural philosopher William Derham and first published[4] in 1714. In that book, Derham deployed the latest astronomical ideas, and his own observations, to demonstrate how the form of the heavens was proof of the existence and benevolence of God.

It is clear that Pantycelyn also drew on other sources of philosophical information to give added weight to his description of God's creation. He rhapsodized about the speed at which the planets moved around the Sun and about the sheer scale of the planets Saturn and Jupiter, and he gave details in the footnotes. Fascinatingly, he speculated about extraterrestial life and its place in creation: "Os haul yw pob rhyw seren sy'n gwibio yn y ne'/Os cylch y rhain mae bydoedd a lloerau'n cadw eu lle/Od oes trigolion ynthynt, neu ynteu nid oes un/Y cwbwl oll a grewyd gan fysedd Mab y Dyn" ("If each star zooming through space is a sun/If they have worlds and moons circling around them/If they have inhabitants or not/They are all creations of the Son of Man"; reference 1, volume 1, page 44). His footnotes added discussions of the latest philosophical views on the plurality of worlds and the likelihood they were inhabited.

Works like *Golwg ar deyrnas Crist* were written for an educated and intellectually curious Welsh readership. Clearly, Pantycelyn thought the scientific material was fascinating and important: It added weight to his theology. But just as critically, he thought that his readers would find it fascinating and important too. And the book's sales confirmed his suspicion—the volume sold enough copies to require a second edition. Beyond its own intrinsic value, *Golwg ar deyrnas Crist* offers a glimpse of a growing Welsh middle class and literary culture that embraced science. Science was an integral element of the cultural world that Pantycelyn and his readers lived in.

Pantycelyn's fascination with the latest science and the explanations it offered of natural phenomena—even when he disagreed—is also evident in a 1774 essay he wrote on the aurora borealis. Pantycelyn wrote that essay in a period when there had been a succession of unusually extensive and spectacular displays of the northern lights.

He described seeing the heavens light up: "o liw gwaed, o liw'r wawr, o liw porffor, ac o liw'r amber; holl liwiau'r enfys" ("colored like blood, like the dawn, like purple, and like amber; all the colors of the rainbow"). It was as if the heavens were dancing: "fel pe buasai am ddodi ofn yn y rhan euog o'r byd; ond creu llawenydd anhraethadwy a gogoneddus yn etifeddion bywyd tragwyddol" ("as if to terrify the guilty of the world; but to create unspeakable and wonderful delight for the inheritors of eternal life"; reference 1, volume 2, page 163). He ran through philosophers' explanations in detail, demonstrating that he knew intimately the latest ideas about electricity and the ether.

None of the explanations were good enough for him, though. Whatever the mechanism, Pantycelyn believed the aurora had been put in the heavens by God as a portent of the great religious revival and reformation that was taking place. The lights blazing in the sky were there to reassure Pantycelyn and his coreligionists in Wales's growing Methodist move-

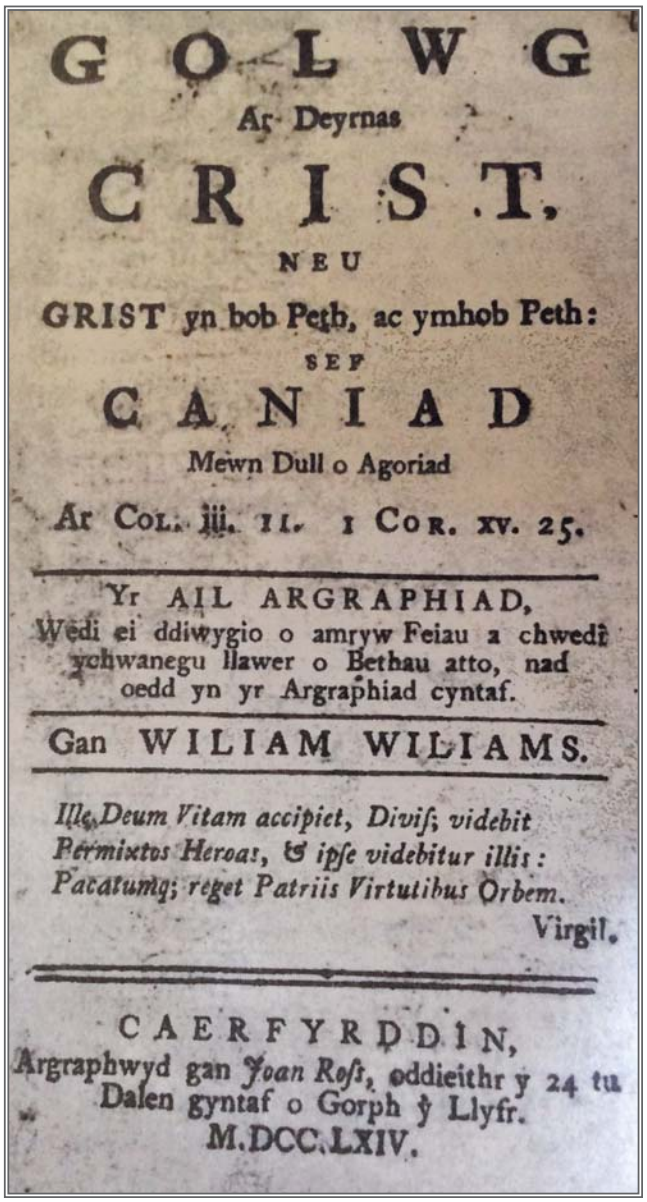
GOLWG
Ar Deyrnas
CRIST,
NEU
GRIST yn bob Peth, ac ymhob Peth:
SEF
CANIAD
Mewn Dull o Agoriad
Ar Col. iii. 11. 1 Cor. xv. 25.
Yr AIL ARGRAPHIAD,
Wedi ei ddiwygio o amryw Feiau a chwedi ychwanegu llawer o Bethau atto, nad oedd yn yr Argraphiad cyntaf.
Gan WILIAM WILIAMS.
Ille Deum Vitam accipiet, Divisq; videbit
Permixtos Heroas, & ipse videbitur illis:
Pacatumq; reget Patriis Virtutibus Orbem.
Virgil.
CAERFYRDDIN,
Argraphwyd gan *Ioan Roft*, oddieithr y 24 tu Dalen gyntaf o Gorph y Llyfr.
M.DCC.LXIV.

FIGURE 1. TITLE PAGE of *Golwg ar deyrnas Crist*.

ment that God was on their side and that their success was assured.

Natural theology and radical politics

Both in his essay on the aurora borealis and in *Golwg ar deyrnas Crist*, Pantycelyn was trying to adapt a tradition called natural theology for a Welsh audience. From the 17th century onward, English natural philosophers such as John Ray argued that the fact that the cosmos appeared to be the product of design was a powerful argument in favor of the existence of a benevolent

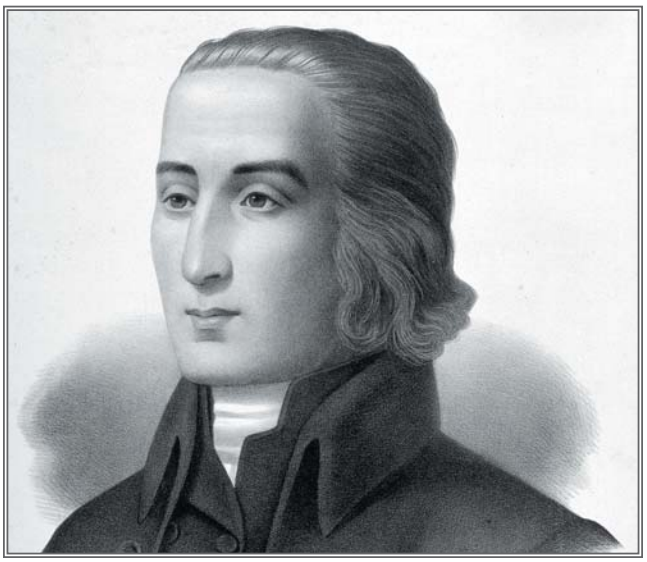

FIGURE 2. WILLIAM WILLIAMS PANTYCELYN, 1717–91. (Courtesy of the National Library of Wales.)

deity.[5] Significantly, Pantycelyn's main source of natural philosophical information was Derham, one of Ray's followers and the author of Ray's biography.

The natural theological tradition seems to have appealed to both Welsh and English readers. During the 19th century, there were translations into Welsh of William Paley's *Natural Theology*, one of the most influential and widely read scientific books of the early 19th century, and of works on natural theology by ministers Thomas Chalmers and Thomas Dick.[6] Again, it demonstrated publishers' belief that there was a Welsh market for scientific ideas and that Welsh intellectuals were anxious to engage with those ideas.[7]

The tradition of natural theology in science was not the only one that appealed to Welsh thinkers and their audiences. Another powerful tradition mixed scientific thinking with radical politics. Richard Price, born to a family of religious dissenters in the Welsh county of Glamorganshire, was a good example.[8] Despite his Welsh roots, Price spent most of his life in England—a Welsh community in London thrived throughout the century. He was a friend of other radical thinkers such as chemist Joseph Priestley, political philosopher Thomas Paine, and Benjamin Franklin.

Like those other radical thinkers, Price's philosophy ranged across science, theology, and politics. In his own writings, Price drew on Priestley's and others' scientific work as he formulated his vision of the rights of man. He made important contributions in the emerging fields of statistics and actuarial science. Price's circle also included his nephews George Morgan and William Morgan, Welsh-born radicals who also spent much of their lives in England. They made important contributions to actuarial science and were avid electrical experimenters. George Morgan was a key contributor to debates at the Royal Society about lightning conductors and their efficacy.[9]

The radical tradition in Welsh science continued well into the Victorian period. Chartists and other working-class radicals were among the founders of local Welsh scientific societies from the 1830s onward. The Mills family, originally from Llanidloes in mid Wales, offers another example of the radical tradition. Edward Mills was an autodidact in astronomy who traveled around the country lecturing with the orrery he had made. His nephew, John Mills, published the radical newspaper *Tarian y Gweithiwr* (*The Worker's Shield*), which like many similar publications paid attention to scientific developments.

Later in the century, Ben Davies, Oliver Lodge's Welsh laboratory assistant, published scientific articles in Welsh in the Liverpool newspaper the *Daily Post*. Davies, like his mentor Lodge, was an avid spiritualist—interested in the scientific investigation of paranormal phenomena. Unlike his mentor, he was also a committed and enthusiastic socialist.

Scientific societies in Wales

Both the radical and natural theological traditions were prominent in the Welsh enthusiasm for local scientific societies that erupted from the 1830s onward. Wales was certainly not unique in that respect—the establishment of such societies surged across the British Isles starting in the late 18th century—but their widespread presence across the country throughout the 19th century is a clear indication of the important place occupied by science in Welsh culture.

In Merthyr Tydfil, for example, establishing the Literary and Scientific Society in 1837 offered a way of trying to unite a town that had been battered by serious and violent industrial unrest only a few years earlier. At the time, Merthyr Tydfil was the largest town in Wales, built around the iron industry—and famous as the place the red flag was first raised as a symbol of workers' power at the barricades during the Merthyr Rising of 1831.

At the Literary and Scientific Society, ironworks owners and workers could unite, at least for a short time, under the banner of science. Taliesin Williams, the son of the prominent antiquarian and Jacobin Iolo Morganwg, was one of its secretaries. Edward Mills brought

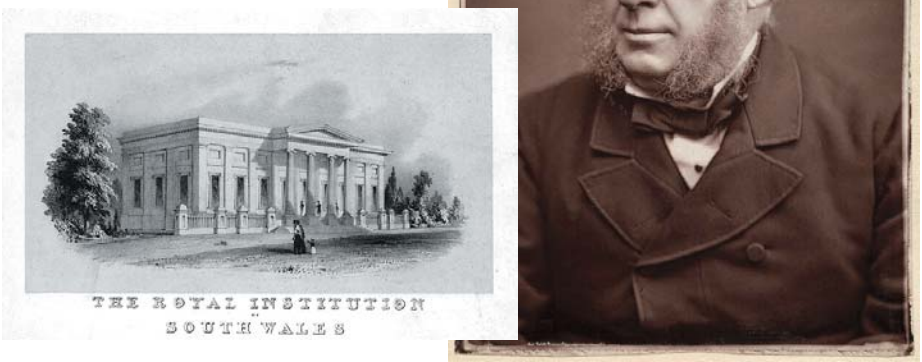

FIGURE 3. WILLIAM ROBERT GROVE, 1811–96 (right) was a major figure in the early history of the Royal Institution of South Wales (left). (Photograph by Lock & Whitfield; copyright National Portrait Gallery, London, NPG x16928. Drawing courtesy of the National Library of Wales.)

his orrery there and repeated his lecture in Welsh for the benefit of the working class, an event recounted in the 16 December 1836 issue of the *Methyr Guardian*. When a public meeting was organized in Aberystwyth in June 1850 to propose the establishment of "a Philosophical, Mechanical and Mutual Improvement Society," local paper *The Welshman* wrote that the organizers were keen to emphasize "the vast disadvantages under which this town laboured for lack of such an institution."

Establishing local scientific societies was about civic pride and ambition as much as anything else. The example of Swansea is telling. By the 1830s Swansea was evolving from a port town to an industrial metropolis, its fortunes founded on copper. Here, the Swansea Philosophical and Literary Society founded in 1835 soon transformed into the even more ambitious Royal Institution of South Wales (see figure 3).

The names that dominated the new institution were those of local industrial dynasties like the Vivians and the Dillwyns, who dominated the town's cultural and political life more generally.[10] Lewis Dillwyn, the first president, was a local porcelain manufacturer, the former sheriff of Glamorganshire, and the member of Parliament for the county. One of the vice presidents, John Vivian, was a prominent copper magnate, the member of Parliament for Swansea, and a deputy lieutenant for the county. Among the first subscribers was John Grove, another local justice of the peace and former mayor, along with his son William Robert Grove, who soon joined the committee.

As the crowd gathered to witness the laying of the new institution's foundation stone, Dillwyn boasted that "if carried on with the spirit with which it has been begun, it will hasten the arrival of the time, and I apprehend that the day is not far distant when Swansea will be generally acknowledged as the Metropolis of Wales."[11] The town's enthusiasm for scientific culture was meant to signal its leading role in national culture too.

FIGURE 4. AN 1875 MAP OF ENGLAND AND WALES. In the 19th century, Wales did not include the county of Monmouthshire, then on its southeastern border. Monmouthshire became part of Wales in 1974. (*Harper's School Geography*, Harper & Brothers, 1875; Universal Photography/Alamy Stock Photo.)

William Robert Grove, chemist and Welshman

William Robert Grove's example demonstrates how important science might be for local elites in Wales (see figure 4) during the 19th century.[12] Grove's family was part of a local dynasty. His father was politically prominent, and the Groves were close neighbors of the Dillwyns and the Vivians, who were also enthusiasts for science. There was some science in the family tree too: His grandfather, also named William, had scientific interests and was a leading member of the Fund for Obviating the Inconvenience Arising from the Smoke Produced by Smelting Copper Ores, and a granduncle was a keen chemist and astronomer.

Following in their footsteps, Grove took up scientific research while studying in London to become a lawyer. He joined the prestigious Royal Institution of London in 1835. His close links with some of Swansea's leading citizens helped him along even in London—both Dillwyn and Vivian were fellows of the Royal Society, and their introductions helped smooth the young Welsh lawyer's entry into the metropolis's elite scientific circles. He would go on to become a professor of experimental philosophy at the London Institution, which made scientific education available to students whose religious beliefs prevented them from attending Oxford or Cambridge Universities.

It is easy to see how Grove's upbringing in industrial south Wales molded his scientific pursuits. He was interested in utility and economy. The nitric acid battery, which he invented in 1839, was developed with efficiency in mind: Grove wanted a battery that generated the biggest possible output for the lowest possible cost. As he told his audience at the London Institution in an 1842 lecture, it was important that "the most recondite scientific discoveries find, ere long, their application to the arts, and add, not only to the mental advancement, but also to the comforts, the luxuries, and the power of man."[13]

The same kind of impetus lay behind Grove's invention of

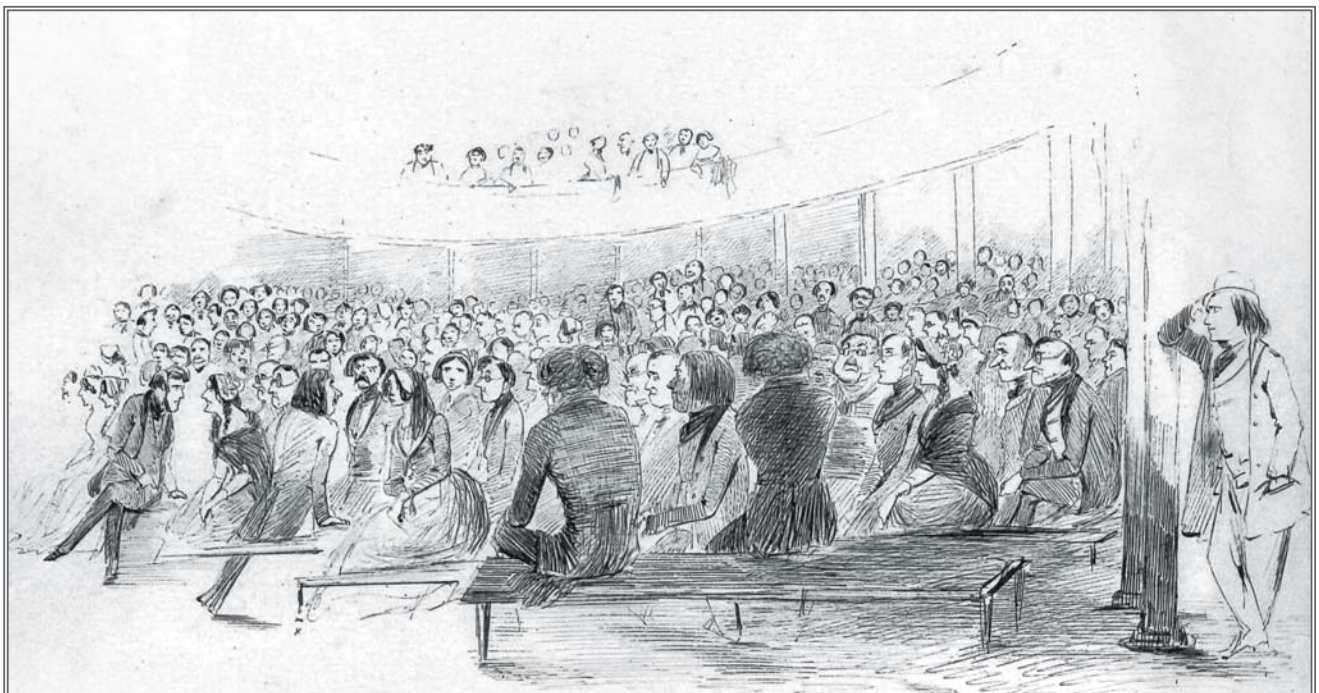

FIGURE 5. SKETCH OF THE 1848 BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE MEETING in Swansea by local artist John Weir Padley. (Courtesy of the National Library of Wales.)

the gas battery, now known as the fuel cell, and the main reason that his name will become increasingly familiar over the next few years. Grove himself thought the gas battery was "a beautiful instance of the correlation of natural forces," as he put it in a piece for the *Literary Gazette* in 1842. Unsurprisingly perhaps for a man from Welsh coal-mining country, in 1845 he also invented an electric light to be used in mines to mitigate the dangers of explosions.

When the British Association for the Advancement of Science (BAAS) visited Swansea in 1848—its first visit to Wales—its presence underlined the importance of science for Welsh culture.[14] The BAAS was a traveling scientific meeting that took place in a different town or city across Britain every summer, and it offered scientific locals the opportunity to rub shoulders with the great gentlemen of science (see figure 5). At Grove's urging, the Royal Institution of South Wales issued the invitation in a deliberate effort to put the town on the scientific map and to consolidate its position both as the "metropolis of Wales" and the country's leading science center. The fact that so many of the era's most famous men of science made the difficult journey to Swansea was a testament both to Grove's rising reputation and to the increasing relevance of Welsh scientific culture.

The marquis of Northampton, Spencer Compton, then BAAS president, described Grove as "a potent magician, or like a representative of the Bard and Druid of ancient Britain" who had "summoned us to the shores of the Bristol Channel."[15] Those slightly patronizing phrases were an example of how Wales and Welsh science could appear to aristocratic English eyes—as wild and a little primitive. But Swansea's townspeople thought the meeting had been a great success and held a public dinner in Grove's honor.

Telegraph, *s.* (Gr. *têle* a *graphô*) pellfynag, pellebyr, brysfynag, brysebyr, hysbysai.
Electric telegraph=(d. g. *Electric*)
Telegraph, *v. a.* pellfynegu, pellebru, brysfynegu, brysebru; hysbysu gyda'r pellfynag; gyru drwy y pellfynag, &c.
Telegraphic, *a.* pellfynegol, pellebrol, brysfynegol.
Telegraphic art—pellfynegiaeth.
Telegraphy, *s.* pellfynegiaeth, brysfynegiaeth, pellebraeth.
Teleological, *a.* diweddegol.
Teleology, *s.* (Gr. *telos* a *logos*) diweddeg=athrawiaeth achosion terfynol pethau.
Teleosaurus, *s.* (Gr. *teleios* a *saura*) cyfrethrychwil, cyfrfadfall.
Telephone, *s.* (Ff.; Gr. *têle* a *phônê*) pellseinyr.
Telephonic, *a.* pellseiniol.
Telescope, *s.* (Ff.; Gr. *têle*, *telos*, a *scopeô*) pell-

FIGURE 6. ENGLISH-TO-WELSH TRANSLATIONS for words associated with the telegraph. (From ref. 17.)

Science in the Welsh language

The BAAS's proceedings were in English, of course, and it seems clear that English was the language of most Welsh scientific societies. But it is also clear that the tradition of science in Welsh remained vibrant throughout the 19th century. There was, as previously mentioned, a tradition of translating important English scientific books—like Paley's *Natural Theology*—into Welsh.

In 1851 a publisher in the Welsh town of Pwllheli took on the mammoth task of translating *Information for the People*, a multivolume educational encyclopedia written by Scottish publishers William Chambers and Robert Chambers.[16] The fact that there was a market for that massive undertaking was a testament both to the number of scientifically informed Welsh speakers who would have been needed to translate the entries and to the publisher's faith that such a market existed. Plenty of scientific books were also written directly in Welsh, such as Edward Mills's *Y darluniadur anianyddol* (*An Illustrated Physics*, 1850) and A. W. Jarvis's *Pwyllwyddeg a mesmeriaeth* (*Living Magnetism*, 1854).

Welsh remained the country's main spoken language until the final decades of the century, when industrialization,

immigration from England, and the perception that English was the language of self-advancement started taking their toll. The first census that attempted to establish the number of Welsh speakers in 1891 indicated that just under a million people—approximately half the population—spoke the language, and that just under a third of the population were monoglot Welsh speakers.

As a result, a Welsh-language periodical press flourished. Articles on the latest science were a feature of periodicals such as *Baner ac Amserau Cymru* (*Banner and Times of Wales*) or *Y Traethodydd* (*The Essayist*), aimed at largely middle-class readers from different nonconformist religious denominations. As early as 1814, an author using the initials "T. E." was writing about astronomy in *Yr Eurgrawn Wesleyaidd* (*The Wesleyan Treasury*). Not all that scientific publishing activity in Welsh was confined to Wales. Liverpool, just over the border in England, had a flourishing Welsh-speaking community, for example, and astronomer Eleazar Roberts was a prolific writer on science for the Welsh periodical press.

Efforts to forge a Welsh scientific vocabulary were central to the publishing activity about science in Welsh, and they worked to counter the perception that English was the language of the future. In his essay on the aurora, Pantycelyn talked about the "gelfyddyd newydd o electricity" ("new art of electricity"). A century later Welsh writers were using the terms "trydan" or "trydaniaeth" for electricity, and the former is still in use in Welsh today. But not all proposed terms—for instance, "tynfaen" for a magnet—survived the test of time.

The enthusiasm for a new scientific vocabulary in Welsh indicates a desire to make science part of Welsh culture. Daniel Silvan Evans, compiler of the monumental *English and Welsh Dictionary: Adapted to the Present State of Science and Literature* (1858), wanted to give the language the tools to deal with science. He and others like him wanted Welsh to be a scientific language. Armed with his dictionary, native Welsh speakers no longer needed to send messages by telegraph; they could use the "pellfynag," "pellebyr," "brysfynag," "brysebyr," or "hysbysai" instead[17] (see figure 6). Like participating in scientific societies, the new Welsh scientific vocabulary showed that Wales had its own forward-thinking culture.

A new perspective

Recovering Wales's scientific history is important because from a Welsh perspective, it is all too easy to forget that this history exists at all. Science, as we have seen, is nearly nonexistent in the stories Welsh people tell themselves about their history and their place in the world. But it is clear that until the beginning of the 20th century, at least, science was very much part of Welsh culture.

Grove offers an interesting example of how taking its scientific history seriously might change the way Wales thinks about itself. After all, if fuel-cell technology fulfills its current promise, what will it do to the way the Welsh people think of themselves if the inventor of that revolutionary technology was a Welshman? Will Grove be celebrated in the same way that the Scots now celebrate steam engine innovator James Watt?

If recovering its scientific heritage is important to Wales, putting Wales and other small countries like it back in the history of science is also important for how we think about science. Looking at the place science occupies in such countries reminds us, paradoxically, of the universality of science and the variety of ways in which it is and has been understood in different cultures and places.

We tend to think of science as moving from the center to the periphery. Looking at Wales shows us that the process of exchange is rather more complex than that picture suggests. Science clearly flowed into Wales from elsewhere, but it was also made in Wales and molded by the Welsh to suit their own purposes. As in other cultures, science in Wales has meant different things at different times to different people. Recovering the variety is an important historical task that matters for contemporary science. Looking where science belonged in a country like Wales should remind us that science is common cultural property. It belongs to all of us and matters for all our futures.

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