Is Kelvin representative of an “Irish tradition”?

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Abstract. Kelvin interacted with many physicists and mathematicians with Irish connections, and these interactions are sketched. A number of suggestions of Irish or Irish-Scottish scientific traditions or networks are reviewed, but it is argued that the large number of interactions may be better explained just by the high quality of physics and mathematics in Ireland and Scotland in the nineteenth century. Kelvin’s disapproval of science as carried out in Cambridge and London is discussed, and an attack by some of his followers on science at Oxford is also described. Finally a number of examples of Kelvin’s most important work are outlined and some general features are pointed out; these include the willingness to tackle practical and engineering problems, and the ability to attempt to construct major syntheses, where appropriate taking note of religious themes, and drawing conclusions, positive or negative, on religious matters. These features are used to construct a highly tentative characterisation of a grouping of Irish and Scottish scientists centred largely round Kelvin.

1. Kelvin and nineteenth century Irish physicists and mathematicians

It has often been remarked that Kelvin had a very high regard for Irish mathematics and physics. As an example, when he became Editor of the Cambridge Mathematical Journal in 1845, he changed its name to the Cambridge and Dublin Mathematical Journal in order to bring in papers, as he said, from all over Ireland, not just from Dublin [1, 2]. (Refs. [1] and [2] are standard excellent biographies of Kelvin that may be consulted with regard to most aspects of his life and work.)

Kelvin also learned from, or collaborated or interacted with, many mathematicians or physicists who were Irish or who had Irish connections. To establish the point, a short list will follow. Most of those listed have brief biographies in either or both of Refs. [3] and [4].

James MacCullagh (1809-47) (figure 1) [5] was an important theoretical physicist from Trinity College Dublin (TCD). His main work consisted of study of the passage of light through solids. We may speak of this as an early contribution to study of the ether, the hypothetical medium through which it was supposed that light must travel. As we shall see, many of the most celebrated Irish scientists of this century concentrated their efforts on study of the ether, and Kelvin himself was heavily influenced by MacCullagh. Sadly MacCullagh’s scientific and political ambitions were not realised, and he was to commit suicide at a comparatively early age.

Today the work of George Boole (1815-64) (figure 2) [6] is known by anyone who uses either statistics or a computer, in the form of Boolean logic. Boole, an Englishman, had no qualifications in mathematics, and much of his early work was performed as an amateur. Kelvin was among those who helped him to obtain his first position as a mathematician, when, at the foundation of the Queen’s Colleges in Ireland, he became the first Professor of Mathematics at Queen’s College Cork in 1849.
He too died early, catching pneumonia after becoming soaked while insisting on walking through heavy rain to give a scheduled lecture.

William Rowan Hamilton (1805-65) of TCD (figure 3) [7-9] was, of course, one of the most creative mathematicians of all time. Today his most celebrated achievements would probably be seen as his important work in optics, including the discovery of conical refraction, and the so-called Hamiltonian mechanics, a hundred years later an indispensable part of quantum theory, with its ubiquitous Hamiltonian function. Kelvin, of course, fully appreciated this early work. However Hamilton himself was most proud of his discovery of the abstract algebra of quaternions. Although most of this work was published under Kelvin’s editorship of The Cambridge and Dublin Mathematical Journal, Kelvin came to consider that “Quaternions came from Hamilton after his really good work had been done, and though beautifully ingenious, have been an unmixed evil to those who have touched them in any way, including Clerk Maxwell” [10]. One such, in Kelvin’s opinion, was Peter (PG) Tait (1831-1901) [11], in every other way one of Kelvin’s closest friends and collaborators.

Tait (figure 4) was a Scotsman and a Cambridge Senior Wrangler [top performer in the Mathematical Tripos], who was Professor of Mathematics at Queen’s College Belfast (QCB) from 1854-60 before moving to become Professor of Natural Philosophy (Physics) at the University of Edinburgh, a Chair that he occupied until his death. His move from Mathematics to Physics paralleled that of Kelvin. In obtaining the Edinburgh position, he defeated James Clerk Maxwell, an obviously superior physicist, presumably because of Tait’s superior teaching ability. The Edinburgh Courant commented that: “[I]n Professor Maxwell the curators would have had the opportunity of associating with the University one who is already acknowledged to be one of the remarkable men known to the scientific world…But there is another power which is desirable in a professor of a University with a system like ours, … the power of oral exposition…. We little doubt that it was the deficiency of this power in Professor Maxwell principally that made the curators prefer Mr Tait [11 pp 16-17].”

It might be said that Tait acted as Kelvin’s “bulldog” in his arguments with evolutionists and geologists over the age of the Earth [12]. With Tait’s support, Kelvin estimated the total amount of energy that would have been available over the life of the Universe. From this comparatively small amount of energy, they deduced that the lifetime of the Earth must have been far shorter than required by the contemporary theories of evolution and geology. While Kelvin’s arguments were broadly correct according to the then state of knowledge, it is usually argued that the discovery of the additional energy supply of radioactivity towards the very end of both his and Tait’s lives was to render their age limits far too low. A recent paper [13], though, suggests that the real difficulty was that Kelvin had assumed that the Earth had a solid rather than a liquid interior, and so his model did
not include convection. The argument continues [14, 15]. Though Kelvin himself was only a mild opponent of evolution, his arguments with Huxley, Darwin’s own “bulldog” (figures 5-7), mainly over the timescales involved for evolution, have damaged his posthumous reputation rather severely.

A more important interaction between Tait and Kelvin was the writing between 1861 and 1866 of the famous *Treatise on Natural Philosophy* [16], always known, after Thomson and Tait, as *T and T’*. This book followed the discovery of the Laws of Thermodynamics by Rudolf Clausius (1822-88) (figure 8), Kelvin, and William John MacQuorn Rankine (1820-72) (figure 9), and in particular the understanding obtained by Kelvin, with the assistance of his brother, James Thomson, of the significance of these Laws in the entire history of the Universe, and of the centrality of the concept of energy throughout this history. *T and T’* was the first book to be based around the paradigm of energy rather than Newtonian force, and so initiated the approach to physics taken for granted by any student of the subject today. As has already been stated, Tait was a great enthusiast for quaternions. Kelvin’s rejoinder was that he would be happy for their inclusion in the book if Tait were able to show that they had ever been of any use, but Tait was unable to do so [17]!

Another scientist with Belfast connections well-known to Kelvin was Thomas Andrews (1813-85) (figure 10) [18], who had been a pupil of Kelvin’s father, James Thomson Senior, at the Belfast
Academical Institution. With the foundation of the Queen’s Colleges in 1845, it seemed highly likely that James, whose prominence by that time at Glasgow University was well-known, would be asked to become the first Principal of QCB. However, by mid-century, the political liberalism of Belfast in the first third of the century had largely disappeared. Henry Cooke (1788-1868) (figure 11), the popular preacher and leader of the Presbyterians in Belfast, had succeeded in breaking the 1798 alliance of Catholic and dissenter, and established the broad division between Catholic on the one hand and all aspects of Protestantism on the other.

Cooke was keen to become President of QCB himself, but, as a minimum requirement, he made it clear that, if any appointments were made to QCB of whom the Presbyterian Church did not approve, no trainee for the ministry would be allowed to attend the college. As it happened, the liberal Thomson and the conservative Cooke were both ruled out, and the position went to Dr Pooley Henry (figure 12), neither an academic nor an educationalist, but as an administrator a safe pair of hands. Thomson was offered the position of Vice-President at a little over half the salary of the President, a position he naturally turned down [19, 20].

The positive result of this debacle was that the position of first, and, as it turned out, only Vice-Principal of QCB went to Andrews, an excellent scientist, who was to carry out the famous Andrews’ experiment, which clarified the difference between a vapour, which may be liquefied by pressure alone, and a gas which may not. This was to be crucial over the future decades as liquefaction of the various gases was steadily achieved.

George Gabriel Stokes (1819-1903) (figures 13 and 71) [21-23] came from County Sligo, and was Lucasian Professor at Cambridge from 1849, as well as being Secretary of the Royal Society for many years and later President. He made discoveries in many areas of physics, being particularly concerned with the properties of the ether, and there are several well-known Stokes’ Laws and Theorems. Despite their geographical separation, he was the scientist closest to Kelvin, and they exchanged innumerable letters [24-25]. Stokes, an Anglican, was an extremely devout man, and was concerned with the links between science and religion.

On the other hand, John Tyndall (1820-93) (figures 6 and 14) [26-29] from Carlow could be described as Kelvin’s greatest scientific opponent, if not enemy. With the support of Michael Faraday (figures 6 and 15), Tyndall became Professor of Natural Philosophy at the Royal Institution and made contributions to many areas of physics, the most important perhaps being the physics of glaciers, as well as being a leading communicator and lecturer. He was a follower of Huxley and a fellow agnostic, and his famous “Belfast address” to the British Association for the Advancement of Science (BAAS) in Belfast in 1874 was a trenchant appeal for materialism, and a demand that any religious input to science should be eliminated. It was clear that his approach to life was entirely opposed to that of Kelvin, but their animosity seems to have gone deeper. It may be that the self-made Tyndall resented the fact that Kelvin had, in comparative terms, rather a privileged upbringing and obtained a prestigious position at a young age. Tyndall’s role in diminishing the claims of Kelvin’s protégé, James Joule (figure 16) in favour of those of Julius Mayer (figure 17) is discussed in section 3. On
Tyndall, Kelvin undoubtedly shared Tait’s views; describing William Grove (1811-96), a well-known physicist of the time, as “woefully loose and unscientific… vague and cloudy”, he still considers him “not [as bad as] a Tyndall, as of course you know, since the latter is unique” [29, p 176].

Another TCD scientist with definite academic links to Kelvin was Samuel Haughton (1821-97) (figure 18) [30], Professor of Geology from 1851, and later, after gaining a medical qualification, Registrar in the School of Medicine, where he was placed by the Provost and College authorities to reform the rather chaotic administration of the School. As a geologist, he was a strong supporter of Kelvin in the controversy over the ages of the Earth and the Sun, and, like Kelvin, his reputation was to suffer when it was shown that their conclusion, if not necessarily their argument, was incorrect. Rather unfairly Haughton may be best known for the so-called “Haughton drop”, the formula based on the weight of a person to be hanged, which ensured death would be instantaneous due to a broken neck, rather than over a considerable period of strangulation.

John Everett (1831-1904) (figure 19) [31] was originally from England, but studied under Kelvin in Glasgow. He was undoubtedly Kelvin’s best student in the 1850s [32], and probably one of the two or three best in the whole of Kelvin’s 53 years as Professor in Glasgow. Everett subsequently became Professor of Natural Philosophy at QCB from 1867-97, and during these years, as well as writing influential textbooks, he became prominent in the task of establishing a set of electrical and other units.

In this project he was following in the footsteps of Kelvin. From the time of his earliest considerations of the Atlantic cable, Kelvin had recognised the importance of accurate determination of the conductance of the copper and the capacitance of the cable as provided by the manufacturers. However this was stymied by the fact there were no national or international standards for electrical quantities. Thus Kelvin was to spend a considerable amount of time taking part in and chairing International Commissions, which not only had the task of determining the most practical means of defining the various units, but also the sensitive one of allocating the names of prominent scientists to the various quantities. Everett took the process further, and his most important role was as Secretary to the British Association Committee for the Selection and Nomenclature of Dynamic and Electrical Units. In 1873 he presented a report recommending the cgs or centimetre-gram-second system of units, and introducing the names of dyne and erg for the fundamental units of force and energy in this system [33]. Today, when we use the mks or metre-kilogram-second system, our units are the Newton, which is equal to $10^5$ dynes, and the Joule, which is equal to $10^7$ ergs.

George Francis Fitzgerald (1851-1901) (figure 20) [34-36] was yet another famous TCD scientist. He is probably most famous for the Fitzgerald(-Lorentz) contraction, the attempted solution to the dilemma of the Michelson-Morley experiment, the discovery that it appeared to be impossible to demonstrate motion through the ether. For Fitzgerald, the suggestion, though certainly brilliant, was made rather casually. Formally the contraction reappears in Einstein’s theory of special relativity, though here the interpretation is rather different; it is an apparent contraction, rather than the real contraction imagined by Lorentz and Fitzgerald. In Einstein’s theory, the impossibility of
demonstrating motion through the ether is explained by the postulate that the ether does not actually exist.

Fitzgerald, though, did much more significant work. Following James Clerk Maxwell’s production of his epoch-making theory of electromagnetism (figure 21), Fitzgerald became the unofficial spokesman for the so-called Maxwellians [37-38] whose self-imposed task was to elucidate and promote all the various aspects of Maxwell’s theory. Apart from Fitzgerald himself, this group included Oliver Lodge (1851-1940) (figure 22), Oliver Heaviside (1850-1925) (figure 23), Heinrich Hertz (1857-94) (figure 24), who was the first to detect the electromagnetic waves predicted by Maxwell, and Joseph Larmor, who will appear later in this list. Earlier in his career Fitzgerald had been a great admirer of Kelvin, but Kelvin’s opposition to Maxwell’s theory inevitably meant that relations between the two became at least temporarily somewhat strained. However, when Kelvin had occupied the Glasgow chair for 50 years in 1896, Fitzgerald contributed the main biographical article to the celebratory volume, presumably signifying his willingness to accept the positive contributions of the older man and ignore those of which he disapproved [39].

John Perry (1850-1920) (figure 25) [40, 41] was an extremely interesting character who cropped up in Kelvin’s life at a number of significant points. He was born in Garvagh in County Londonderry, and though he left school at the age of 14 to take up an apprenticeship, he gained scholarships to study at QCB, working under James Thomson and obtaining his MA. As mathematics master and physics lecturer at Clifton College in Bristol from 1870-84, he set up the first physics laboratory and the second mechanics workshop in an English school. He subsequently worked as an assistant to Kelvin for a year, and then, with William Ayrton (figure 26), took Kelvin’s influence to Japan as joint
Professors of Engineering [42]. An important contribution to physics of the pair during this period was an accurate determination in 1878 of the speed of light using telegraphy; this value was considerably closer to that predicted by Maxwell than those of the previous best measurements, giving enhanced experimental backing to his theory [29].

From the 1880s, Perry and Ayrton were both back in England as Professors at Finsbury Technical College, later to become part of Imperial College London. Perry was Kelvin’s main critic from the physics world in the controversy over the age of the Earth [12]. He actually considered Kelvin’s arguments to be correct in principle, but suggested that he had used detailed assumptions which were somewhat arbitrary, and which affected his results quite significantly. Perry preferred the liquid to the solid interior of the earth [13-15].

During this period, Perry and Ayrton published many scientific papers, and were also responsible for a vast number of inventions, for example the first block system for electric railways, the first electric tricycle (figure 27) and many electrical measuring instruments. Perry was a great champion of technical education, giving classes for working men, and also of mathematics for engineers and scientists, and he published many textbooks in this area. He also made a very great improvement to the slide rule (the so-called System Perry) [43], and stressed the importance of graph paper, at the time extremely expensive; Perry was able to achieve an enormous reduction in cost. Perry and Ayrton will appear again shortly in this account.

Figure 28
Joseph Larmor

Figure 29
Paul Dirac

Figure 30
John Townsend

Another very important figure, much younger that Kelvin, who interacted with him very significantly, was Joseph Larmor (1857-1942) (figure 28) [44-46]. He was a native of County Antrim, and he studied first at QCB, before moving to Cambridge where he became Senior Wrangler in 1880. He was Professor of Natural Philosophy at Queen’s College Galway (QCG) from 1880 to 1885, subsequently returning to Cambridge as a lecturer before succeeding Stokes as Lucasian Professor in 1903. He himself was succeeded in this position by PAM Dirac (figure 29) in 1932.

Larmor’s important researches were in electromagnetism and the ether, and he had many discussions with Kelvin in this area of physics. It is now recognised that he was the first to write down the so-called Lorentz transformation equations, which are of crucial importance in special relativity. Larmor is best known for the his discussion of the radiation from a moving charged particle, while in the theory of magnetic resonance, the Larmor precession and its associated Larmor frequency are absolutely central. Larmor edited the collected works of both Stokes and Kelvin.

Last to be mentioned in this brief list is John Townsend (1868-1957) (figure 30) [47], who came from Galway, and studied at TCD under Fitzgerald and worked with JJ Thomson in Cambridge on ion physics before becoming the first Wykeham Professor of Physics at Oxford in 1900. By this time
Kelvin was in his mid-70s, but he wrote references for Townsend, and, once the latter had been appointed to the Oxford position, took considerable pains to assist in him obtaining a Royal Society grant for equipment [48].

2. Was there an ‘Irish tradition’?
It is natural to speculate whether Kelvin’s interactions, some negative but the great majority positive, with scientists from Ireland show that he was part of an Irish scientific and mathematical tradition. This speculation may be followed up in several very different directions.

First we may note the argument of Ivor Grattan-Guinness [49, also 44] that there is a clear line in the study of the ether from the physics of MacCullough and the mathematics of Hamilton to the radical ideas of Fitzgerald and thence of Larmor. Haughton also carried out some admittedly less important work along the same lines, and it is noticeable that, of these five, only Larmor was not from TCD. Kelvin and Stokes also spent large portions of their careers studying models of the ether, so it is clear that Irish mathematicians and scientists were important contributors to such work throughout the nineteenth century.

In *Prometheus’ Fire*, Norman McMillan [28] argues that the idea of an Irish tradition is insufficient to explain “the importance and success of the Irish in British science and engineering”, and suggests instead the idea of an *Irish network*, not in any way as formalised as the X-club of Huxley and colleagues, but nevertheless a group of people with quite strong social cohesion, prepared to exchange advice and opinions, and also to help each other into positions of importance and influence, and provide assistance in gaining fellowships and honours.

McMillan includes in his discussion Edward Sabine (1788-1883) (figure 31), a military engineer and explorer originally from Dublin, who was President of the Royal Society (RS) from 1861-71, but had been Secretary, Foreign Secretary and then Treasurer for a total of 19 years before that. He had also been Secretary to the BAAS from 1839-59 except for the year of 1852 when he acted as President. McMillan mentions that Sabine assisted Stokes and Tyndall to become FRS in 1851 and 1852 respectively; he hoped that they would aid him in the continuing process of reforming the society. Sabine also actively worked for Kelvin’s election in 1851; in this case his particular aim seems to have been to achieve theoretical support for Sabine’s own labours in terrestrial magnetism [50].

McMillan describes in more detail Stokes’ work as Secretary of the RS from 1854-85. (He was later President from 1885-90.) McMillan discusses informatively the support he gave to Tyndall, despite the fact that the two had drastically divergent views on religious, and to an extent, social
matters; to Howard Grubb (1844-1931) (figure 33) [51], most famous, with his father, Thomas (figure 32), as a designer and manufacturer of telescopes, and whose optical company received a vast amount of technical advice from Stokes; to the Third Earl of Rosse (1800-67) (figures 34 and 71) [52], responsible for the construction at Birr of the largest telescope in the world at that time; to Robert Mallett (1810-81) (figure 35), founder of the science of seismology and vulcanology; to John Casey (1820-91)(figure 36) [53], a poverty-stricken schoolteacher, who Stokes helped to eminence as the most famous mathematician who has been associated with the Catholic University of Ireland and its successor institution, University College Dublin (UCD); to Fitzgerald, as he commenced his analysis of Maxwell’s work; and to several others with Irish connections, including Haughton.

McMillan points out that Stokes, who could select from papers submitted to the Royal Society those he wished to review, in fact reviewed papers written by 22 Irish authors, which represented a statistically higher proportion than for non-Irish authors. Of his help to scientists, McMillan says that: “It seems a historically determined fact that he reserved most of his help for those from his homeland.” Indeed McMillan says that archives of other Irish scientists, including Sabine, Tyndall, Fitzgerald and George Johnstone Stoney (figure 37), show the same Irish “connectivity”, and he calls for a careful study of “the many successes in the government of British science and engineering through the active co-operation of the Irish in furthering their own careers and their own specific national interests”. (Stoney [54], who was Professor of Natural Philosophy at QCG from 1852 to 1857, and then Secretary to the Queen’s University administration in Dublin until 1882, was also a prolific physicist, best known today for having named the electron.)

An interesting test of these ideas is whether Kelvin received particular support from Irish people when he applied for the Glasgow chair in 1846. Smith and Wise [1, p 277] comment that, at their 1844 meeting: “No doubt Sabine represented to Thomson the possibility of support in high places for the forthcoming campaign for the Glasgow chair.” Help behind the scenes may have been forthcoming, but Sabine is not on the list of those providing testimonials given by Thompson [1, pp 167-8], which includes Hamilton, Stokes, Boole and Humphrey Lloyd (1800-81) (figure 38) [55], thus only 4 with strong Irish connections out of around 30 on the list. (Lloyd was an experimental physicist, later Provost of TCD; today best known for the so-called Lloyd’s mirror, a clear demonstration of the wave nature of light, but probably more important for his setting up of Magnetic Observatories at TCD and throughout the world.)
McMillan’s ideas on the network were originally put forward specifically for Irish astronomers [56]. Nicholas Whyte [57], however, questions the use of the term network. Whyte’s own model of a network is the so-called Cambridge Network (figures 39-44), which was active in the second quarter of the nineteenth century. It included scientists such as Charles Babbage, John Herschel, George Peacock, George Biddell Airy, William Whewell and Adam Sedgwick, and its self-imposed task was the reform of British science, which involved modernising British mathematics and in particular its teaching at Cambridge, attempting to obtain control of the Royal Society, and stimulating the BAAS. To this end they worked together and provided mutual support, and, to an extent, patronage. Whyte does not believe that these elements were present in the Irish case.

However he supports the idea of an Irish astronomical tradition. He notes the foundation of the Dunsink Observatory near Dublin in 1775, and the Armagh Observatory in 1792. As well as several of the characters we have already met – Hamilton, Rosse and the Grubbs, Whyte includes in the tradition Thomas Romney Robinson (1793-1882) (figure 45), astronomer in Armagh; Edward Joshua Cooper (1793-1863) (figure 46), who built up another flourishing private observatory; Sir Robert Ball (1840-1913) (figure 47), astronomer at Dunsink, and later Professor of Astronomy at TCD and Cambridge, and while at TCD, Astronomer Royal for Ireland; Agnes Clerke (1842-1907) (figure 48), who wrote a number of extremely popular histories of astronomy and cosmology; and many others. William Wilson (1851-1908) (figure 49) was also an important Irish astronomer with a series of telescopes at his family estate of Daramona.
Whyte also points out another feature tending to create communication and support among Irish astronomers and indeed the wider scientific community – the fact that there were many family and other personal relationships. Stokes married one of Robinson’s daughters. Robinson himself was the uncle of WH Rambaut, assistant at Birr and Armagh in the mid nineteenth century, who was himself the uncle of AA Rambaut, assistant at Dunsink at the end of the century. Ball’s first job was as tutor to Rosse’s children, who included Charles Parsons (figure 50), later a distinguished engineer, who was to buy the company founded by Thomas Grubb. GJ Stoney had a brother, Bindon Blood Stoney (1828-1909) (figure 51), who was famous as the engineer responsible for Dublin’s harbour, and he was also the uncle of George Fitzgerald and Maurice Fitzgerald, George’s brother, who was Professor of Engineering at QCB. And Whyte gives many more examples. Incidentally McCartney [47] notes that, at Cambridge, Ball made a point of giving hospitality and support to those from Ireland, including Townsend.

Before analysing these ideas, we note that it might seem entirely natural to extend the tentative idea of a tradition to include Scotland as well as Ireland. This would recognise that Kelvin had his whole professorial career in Glasgow, Tait was of course very much a Scotsman, and several others of those mentioned, such as Everett and Perry, worked with Kelvin in Scotland. Also it particularly recognises the close relationship of Kelvin with Maxwell, who, could be regarded as Kelvin’s ‘protégé’ [58]. In their lively and often jocular communications it was as natural for [JC] Maxwell to be \( \frac{dp}{dt} \), because of the well-known physics equation written in standard notation as
\[
dp{t} = jcm, 
\]
as for Kelvin and Tait to be \( T \) and \( T' \).

Crosbie Smith [29] takes this further in his book *The Science of Energy* by introducing an “identifiable, though informal, network of scientific practitioners” which he calls the *North British group*, who worked strenuously in the mid nineteenth century to produce a theory of energy and to make practical use of that theory, and to worked equally strenuously to establish practically total priority for the members of their group, and so to establish their own reputations as among the most important scientists of all time. Smith picks out, as locations for the work and promotion of the network, Scottish Universities, marine engineering works, and local and national scientific societies, in particular the BAAS. He gives the main names involved as Kelvin, Maxwell, Joule and Rankine, with Tait, Fleeming Jenkin (figure 52) and James Thomson (figure 53) standing somewhat lower than these.

Of the newer characters, James Joule (1918-89) (figure 16), an independent scientist from Manchester, is generally recognised as establishing the mutual interchangeability of heat and work, and thus, particularly in the view of the North British scientists, providing the First Law of
Thermodynamics. Fleeming Jenkin (1833-85) was born in England but went to school in Edinburgh, finally graduating at Genoa. He was working as an engineer in England when he became associated with Kelvin, assisting him on telegraph cables and many of his inventions. Jenkin was actually a man of considerable erudition, writing on a wide range of scientific and conceptual issues, and he became Professor of Engineering at Edinburgh in 1868.

Rankine (Fig 9) was originally from Edinburgh and worked principally as a railway engineer before becoming interested in the late 1840s in the study of heat, work and engines. His model of molecular vortices provided a clear example of the conversion of heat to work. (The reverse process is less problematic, and may be said to have been demonstrated in the much earlier experiments using friction of Sir Humphry Davy (figure 54) and Count Rumford (figure 55), even though the significance of these was not widely accepted at the time.) Rankine’s work strongly influenced that of Kelvin, and, as already stated, Rankine may be regarded as one of the three founders of thermodynamics, along with Kelvin and Clausius (of whom, see later), although Rankine’s work, being based on models, could be regarded as less profound than that of Kelvin or Clausius. In the 1850s, Rankine helped to establish the practical credentials of thermodynamics by designing actual engines, as another engineer, James Thomson, Kelvin’s brother, had done earlier, and Rankine became Professor of Civil Engineering at Glasgow in 1855. Following Rankine’s death, James Thomson would be his successor.

The term *North British* is usually used as little more than a synonym for *Scottish*, rather than referring, for example, to the northern parts of England and Ireland as well. (If it were to reach as far south as Manchester and Joule, it would have to cover a very large fraction of the British Isles!) When Smith (p 313) wishes to include Ireland he specifically refers to *West* as well as *North Britain* [59]. Thus, in this excellent book, an extremely important aspect of Kelvin’s work appears to be divorced from Irish links [60]. We shall return to the question on Kelvin – (simplistically) Irish or Scottish? – later.

We have looked at suggestions for a variety of different types of group and alliance, and doubtless all contain much truth; certainly each may be used as the basis for an informative account of the history involved. (Another interesting paper considering the question of an Irish tradition specifically in mathematics has been written by Raymond Flood [61].) Yet one may wonder if at least part of the reason for Kelvin’s interaction with many Irish and Scottish mathematicians and physicists is just that many of the best mathematicians and physicists in his lifetime were Irish and Scottish!
Of the Irish contingent, one might supplement our original list and those given since by the names of, for example, Nicholas Callan (1799-1864) (figure 56) [62], Professor of Natural Philosophy at Maynooth College, where Catholic clergy were trained, and known as the inventor of the induction coil; John Joly (1857-1933) (figure 57) [63], another great TCD figure, famous for many inventions including the steam calorimeter, who also made advances in geology and geophysics; Thomas Preston (1860-1900) (figure 58) [64], Professor of Experimental Physics at UCD, discoverer of the anomalous Zeeman effect and author of two famous physics textbooks; and Frederick Trouton (1863-1922) (figure 59) [65], originally from TCD, but from 1902 Professor of Physics at University College London, best-known today for “Trouton’s law” relating boiling points and latent heats, but whose most important achievements were his experimental studies of the applications of Maxwell’s Laws.

More names could be added, as is true also for Scotland.

Indeed Herries Davies [66] comments that: “Quite simply, many of Ireland’s scientists in the period 1780 to 1880 were among the world’s leading scientific figures.” It is also of interest that in the earliest days of the BAAS [67-8], Ireland and of course, Scotland were prominent. After the first meeting of 1831 in York, and meetings in the following years in Oxford and Cambridge, the 1834 and 1835 meetings were in Edinburgh and Dublin respectively, and the Association visited Cork in 1843. Indeed the choice made by David Brewster (figures 6 and 60) of York for the first meeting was because it was “the most centrical [sic] city for the three kingdoms” [68 p 2, 34], while Morrell and Thackray [67, p 99] describe Oxford, Cambridge, Edinburgh and Dublin as “the four great academic centres of Britain”.

Once the point is suggested that Irish and Scottish scientists were particularly prominent for the greater part of the nineteenth century (and we may agree with Herries Davies that there was a decline in the last twenty years), it is not hard to suggest a reason. By the beginning of the nineteenth century, university education had been established for many centuries at four cities in Scotland, and while the history of the institutions had been turbulent, there had been considerable achievement, irregular as it had been. Vivian Green [69] has written of these universities in the eighteenth century that: “While these universities were not free from the abuses seemingly endemic in the ecclesiastical and intellectual life of eighteenth-century Britain, such as nepotism, patronage, facetiousness and neglect of duty, as centres of learning and intellectual activity they could claim to be superior to Oxford and Cambridge.”
Though many of these abuses remained into the nineteenth century, and in Glasgow were strenuously opposed by Kelvin’s father and Kelvin himself, there was further progress, and at the very least reasonably stable and secure conditions in which excellent scholarship and research was possible. In Dublin too, TCD was well-established, and, for all Fitzgerald’s frustrations with the slow pace of curriculum reform and for the lack of support for applied research, there was a clear opportunity for him and others to carry out productive work.

The situation in England and Wales, considering its far greater population, was far patchier. There were, of course, Oxford and Cambridge, where the level of achievement was high if not necessarily consistent. They will be discussed in the following section. There were developments in London and Durham in the first half of the nineteenth century, and then the steady foundation of the civic or “redbrick” universities in the second half of the century and into the twentieth. Despite the good intentions of the founders, which outside London and Durham, where there were special agendas [69], were usually to provide well-qualified manpower to aid the industrial development of the various regions, progress was slow. Without support from government, there was in most cases little enough money for buildings and a bare complement of staff, and none for personnel or facilities for research. Bristol University, for example, survived for decades on support from the Wills tobacco family.

When Sheffield University applied to join Manchester, Liverpool and Leeds as a member of the Victoria University in 1898, it was turned down on the grounds that “its facilities were inadequate, its premises poor, its finances unbalanced and its pupils of mediocre quality”; a judgement which Green [69, p 116] considers unfair, not because it was untrue, but only because “there was hardly a university outside of Oxford and Cambridge of which this was not true at some time in the nineteenth century.” It is scarcely surprising that the level of scientific achievement at the civic universities was extremely low until the last decades of the nineteenth century when, with a small amount of support from government, conditions improved marginally and such men as Oliver Lodge (figure 22) and John Poynting (1852-1914) (figure 61) performed excellent work.

Incidentally it is of interest that Kelvin strongly supported independent rather than federal universities. Shortly before his death in 1907, he argued [1, p 1205-6] that QCB should become independent, which did happen the following year, and he added that QCC and QCG should also be given their independence and that the Victoria University should likewise be broken up. As early as 1885, he had supported his former assistant, Andrew Gray, by then Professor of Physics at the University College of North Wales at Bangor, by opening Gray’s new physical laboratories and giving an address [1 p 845]. Gray later became Kelvin’s successor (figure 62). It is clear that Kelvin had a great faith in university education despite the general financial difficulties of at least the newer universities during his lifetime.

Through the nineteenth century, though, it seems quite natural that Ireland and Scotland could make a substantial contribution to physics and mathematics in the British Isles. The anomaly appears
to be the Queen’s Colleges, and in particular QCB, which one might expect, at first sight, as a new foundation to be broadly equivalent to the English and Welsh civic universities. Yet, as we have seen, QCB provided a substantial contribution to the development of physics and mathematics, much of it as early as the 1850s. Andrews was there, of course, from the outset, Tait and James Thomson were both appointed in 1854, and Perry was a pupil of Thomson, while Everett came in 1867. Relationships were important: Thomson helped Andrews to analyse his experiments; Tait assisted Andrews in their joint and important experiments on ozone, and warmly acknowledged Andrews’ guidance as he moved from mathematics towards physics [11 pp 12-3]; Perry described Thomson as “one of the kindest of men with a strong sense of duty” [40].

The reason for the good showing of the Queen’s Colleges and QCB in particular may be that, since they were essentially government foundations, there was far more stability than for the English civics. The official history of QCB [20] does not suggest that finances were strong and professors happy with their salaries, indeed quite the reverse [20 pp 146-7], but one would suspect that the situation was still sufficiently favourable compared to the rather hand-to-mouth existence of the English civics that professors could concentrate on academic studies to a greater extent. And the appointment of Andrews from the start was certainly a master-stroke.

3. Kelvin: Cambridge, Oxford, London and abroad
It has been suggested that, at least for most of Kelvin’s life, the greatest opportunities for successful scientific work in Britain were in Ireland and Scotland on the one hand, and Oxbridge and London on the other. In the case of London, we refer not so much to the nascent colleges as to the central institutions, in particular the Royal Society and the Royal Institution. In this section we discuss principally Kelvin’s negative, or at least ambivalent, attitude towards Oxbridge and London.

We start with Cambridge and London. Cambridge, of course, helped Kelvin to become a great mathematician. It may be easy to lose sight of this in the light of his later achievements in science and engineering. While there was abundant testimony to his mathematical ability during and soon after his Cambridge years, independent support may be useful in the person of twentieth-century mathematician and historian of mathematics, Clifford Truesdell (figure 63) [70]. Truesdell notoriously insisted that a thermodynamic proposition had not been demonstrated until it had been proved with full rigour; a few central ones, he decreed, had had to wait till the twentieth century and the work of Truesdell himself.

Truesdell was contemptuous of the mathematical ability of some of the famous names from the history of thermodynamics. Of Clausius, he (p 206) said “Few mathematical physicists have shown so little sense of the right mathematics for the job.” He remarked that Joseph Fourier (figure 64), by most people considered an immensely important mathematician, and certainly a crucial
inspiration for Kelvin, was “boastful and discursive” (p 53); that “Of creative conceptual mathematics there is no example in Fourier’s book” (p 77); and that “Among mathematicians commonly reputed great, Fourier sets a record [for lack of quality].” Truesdell is by no means uncritical of Kelvin’s actual work on thermodynamics. He reports (p 168) that Kelvin’s first main paper, published in 1849, was “enthusiastic, rambling, vague”. Of his second paper of 1851, Truesdell (p 224) writes that it is “verbose and rambling” and that “this paper, like Kelvin’s first one, disappoints a critical student. In its vacillation and obscurity the author of Kelvin’s masterful and brilliant researches on electrostatics, hydrodynamics and elasticity can scarcely be recognized (p 234).” Even the ultra-critical Truesdell, however, was forced to admit (p 168) that “Kelvin was an expert and creative mathematician of the highest order”.

So Kelvin owed much to Cambridge. He had enjoyed the music and rowing as well as the mathematics. He was a special Life Fellow of Peterhouse from 1872, and was particularly generous towards his old college. There can be no doubt that he enjoyed his visits back to Cambridge particularly perhaps in his earlier years back in Glasgow. Yet it is crystal clear that he regarded the possibility of a permanent return there with disdain. He was offered the Cavendish chair there three times, when it was founded in 1871 and also in 1879 and 1884. On each occasion he rejected the offer, the eventual occupants being Maxwell, Lord Rayleigh (figures 65 and 71) and JJ Thomson (figure 66) respectively.

One may begin to see his reasons in a letter he wrote to Stokes in 1859 at a time when Kelvin was desperate to get Stokes to come to Glasgow to succeed John Nichol (figure 67) as Professor of Astronomy. As well as occupying his chair at Cambridge, Stokes was also Professor at the School of Mines and was Secretary of the Royal Society. Kelvin wrote of London as well as Cambridge as “those great Juggernauts under which so much potential energy for original investigation is crushed”. (Stokes did not apply for the job, because as a devote Anglican, he did not feel free to declare himself a Presbyterian in the still-existent religious test, even though Kelvin assured him the test had become little more than a matter of form.)

Another aspect of Kelvin’s ambivalent, even negative, feelings towards working in Cambridge may be seen in his remarks about the work of Arthur Cayley (1821-95) (figure 68) [71]. Cayley had been a contemporary and friend of Kelvin’s at Cambridge. Despite being a brilliant mathematician, he was unable at first to obtain a suitable position and worked for 15 years as a lawyer before being invited to become the first occupant of the Sadleirian Chair of Pure Mathematics at Cambridge. His work on groups, matrices and invariants won him everlasting fame, but no plaudits from Kelvin who wrote “Oh that the CAYLEYS would devote what skill they have to such things [elasticity] instead of pieces of algebra which possibly interest four people in the world, certainly not more…..It is really too bad that they don’t take their part in the advancement of the world.”

Nineteenth-century Cambridge was, of course the home of the mathematical tripos, which was devoted to what today might be called applied and applicable mathematics. Applied mathematics may be defined as the mathematical solution of physical problems, and applicable mathematics as mathematics created specifically for the solution of such problems. Yet, as Warwick [46] says, Kelvin was probably correct to detect and criticise early signs of a growing interest on pure mathematics,
study of mathematics for its own intrinsic interest. Indeed such interest was clear in the foundation of the Sadleirian Chair; by the end of the century it would have diluted the thrust to application in the tripos, and in the twentieth century pure mathematics would become probably the most prestigious area of mathematical study and research.

Having studied Kelvin’s approach to Cambridge and London, it is natural to move on to Oxford [72] but it is well-known that physics at Oxford was weak through the nineteenth century, and indeed at least to the 1920s or 30s. For the later part of this period it is natural to put much of the blame onto Robert Clifton (1836-1921) (figures 69, 71), Professor of Experimental Philosophy from 1865 to 1919, whose contribution to research in that lengthy period might be described as negligible, perhaps even negative. Clifton was appointed to the position with high hopes, good references and, according to Gooday [73], a “warm rapport” with Kelvin. From the point of view of this paper, it is interesting that one of the main events that helped to destroy these hopes was brought about by two of Kelvin’s followers, John Perry (yet again!) and William Ayrton.

In fact Clifton had an early great success in achieving the construction of the Clarendon Laboratory for physics in 1870. This actually predated Cambridge’s Cavendish Laboratory by 4 years, and in fact, when helping to design the Cavendish, Maxwell used plans of the Clarendon given to him by Clifton [73]. Indeed, as Graeme Gooday [73] points out, though even at the time it would have been well-understood that Maxwell’s achievements in research were vastly greater than those of Clifton, it is not necessarily the case that he was initially more successful than Clifton across the board of the tasks involved in running a new laboratory – effective teaching, encouragement of research, staff training and so on. It would seem that both struggled.

In 1873, however, Clifton was guilty perhaps of rather arrogant behaviour, which must often have come back to haunt him in future years. In June, Perry applied for a fellowship at Clifton’s own college, Merton, and was informed that he was indeed eligible. However when he arrived for the examination in October, he found out that his QCB MA was not sufficient to allow him to take the examination, and he wrote a letter [74] published in Nature criticising the college for misleading him, and also for refusing him access to the apparatus of the Clarendon to prepare for the examination. Clifton’s response [75] was somewhat patronising, and Perry’s final response [76] clearly highly frustrated and extremely resentful of Clifton. Certainly Perry would be hoping to get his own back.

The opportunity came sooner than he might have dared to expect. At the time there was much discussion over the source of voltaic action, and in particular a debate between Kelvin and Maxwell. Ayrton and Perry were at the time in Japan, and in 1875-6 carried out an extensive experimental investigation of the topic, the results of which, they claimed, strongly supported the position of Kelvin. They sent a draft to Kelvin himself, who read it at the 1876 BAAS meeting in Glasgow.

**Figure 69**
Robert Bellamy Clifton
[Clarendon Laboratory]

**Figure 70**
Frederick Lindemann, Lord Cherwell
[Clarendon Laboratory]
Meanwhile Clifton, in gaps between teaching duties, had carried out experiments on the same topic, though unfortunately not at the same level of sophistication as the Japanese ones. Clifton had unresolved problems with aspects of his experiment, but nevertheless in May 1877 sent an interim account to the Royal Society, expressing the hope that, at a later date, he would be able to send a more satisfactory and complete paper. He had been elected FRS in 1868, presumably out of respect for his Oxford chair rather than his very limited research achievements. (Indeed, despite these achievements remaining low, he was later a member of the Council of the Royal Society, and actually Vice-President from 1896 to 1898 [73 p 113].) So it was not surprising, though unfortunate for all concerned (except perhaps Perry), that his paper was speedily published [77]. The paper did not refer to the Japanese work for the very good reason that Clifton had not attended the Glasgow meeting and was unaware of it.

When Ayrton and Perry saw this paper in December of 1877, they apparently thought at first that Clifton was attempting to claim priority over their own paper, but also came to the conclusion that his paper displayed misunderstanding of practical matters and evidence of poor experimental technique. (Clifton, like Kelvin and Tait, had made the move from mathematical studies as a Cambridge wrangler to experimental work. Five years as the first Professor of Natural Philosophy at Owens College, Manchester, had made him a skilled and painstaking user of relatively standard equipment, but probably not as adept at the design and management of challenging experiments.)

Ayrton and Perry quickly sent a paper to the *Telegraphic Journal* [78], which not only emphasised their own priority, but also included a sustained and savage criticism of Clifton’s work. They followed this up with an account of their own work [79] that did not deign to cite Clifton’s paper at all. As Gooday says [73], it is unsurprising that Clifton never published a research paper again, and thus any hope that the Oxford physics might rival that at Cambridge disappeared for many decades. Much later in 1903, Perry himself was to launch a savage and sustained broadside (around 11 thousand words!) against what he considered to be the highly negative attitude displayed to science at Oxford [80].
It should be mentioned that, as we saw in section 1, Townsend was appointed to a second chair of physics in 1900. Though most of his energies appear to have been dissipated in quarrelling with Clifton, until the First World War his work was not unsuccessful. Indeed Lelong [48] is prepared to talk not only of “Townsend’s growing prominence” but also of “the fall of JJ Thomson as the international expert in discharge physics”. However after the war Townsend completely failed to keep up with modern physics, relativity and particularly quantum theory, and for the last twenty or so years of his career up to 1941, when he was “asked to leave”, his laboratory was perhaps as big an embarrassment to Oxford as Clifton’s had been. Clifton’s successor from 1919, Frederick Lindemann (figure 70) [81-3] (later Lord Cherwell and effectively Winston Churchill’s scientific advisor during the Second World War) was able to persuade a few eminent scientists to work in the Clarendon between the wars, though they remained very much individuals. It was not until after the Second World War that Oxford physics had anything like the strength in depth to be expected in a major university.

Figure 72
Hermann von Helmholtz

Figure 73
Sadi Carnot

Figure 74
Josiah Willard Gibbs

Figure 75
George Green

Having briefly discussed the views of Kelvin and his supporters on the state of physics and mathematics in the various parts of the British Isles, we may even more briefly mention their response to competition or suspected competition from outside. For Europe, we mention the three most important examples [1, 2, 29]. Hermann Helmholtz (1821-94) (figure 72) is today recognised as one of the foremost among the founders of the idea of energy and its conservation. He owed much to early recognition by Kelvin, and the two remained on close terms. One might suspect, though, that this relationship was conditional on Kelvin’s part to Helmholtz refraining from over-asserting his own claims. Julius Robert Mayer (1814-78) also made early, though perhaps somewhat incoherent, suggestions in this area. In 1862, Tyndall took the opportunity of attacking Kelvin’s group by claiming priority for Mayer over Joule in the matter of the equivalence of heat and work. Tait in particular responded with the greatest vigour [29, Ch 9].

We now turn to Clausius. Today, though it would be recognised that many scientists played a role in the understanding of thermodynamics, and Kelvin and Rankine played crucial roles, it was Clausius who actually achieved the synthesis first. Indeed, in his earliest papers on thermodynamics, Kelvin gave him reasonable credit, dividing that for the Second Law between Sadi Carnot (figure 73) and Clausius himself. In 1868, though, in his book Thermodynamics [84], Tait rewrote history by taking Clausius’ term “entropy” and applying it to an entirely different quantity, the available energy. In Maxwell’s Theory of Heat [85] of 1871, the role of Clausius was reduced to the extent that he was forced to complain that “[M]y writings are left quite unmentioned; and my name occurs only once, when it is said that I introduced the word entropy; but it is added that the theory of entropy had already been given by W. Thomson. Hence any one who derives his knowledge of the matter solely from this book must conclude that I have contributed nothing to the development of the mechanical theory of heat” [86, 29 p 257]. For the next few years Tait and Clausius continued to bicker over Clausius’ contributions to thermodynamics, Tait not only questioning Clausius’ priority, but criticising the content and style of his work.
Overall we may surmise that Kelvin and his friends were pleased to maintain good relations with scientists from other nations in Europe provided, but only provided, these scientists were prepared to recognise the general priority of their British colleagues.

Very briefly we look even further afield to the American Josiah Willard Gibbs (1859-1903) (figure 74) is today recognised as having instigated very important developments of thermodynamics. Smith [29] reports that Maxwell became an advocate of Gibbs’s work (p. 260), but Kelvin strongly disagreed (p. 303).

4. The Kelvin tradition
We have seen that, while we may not need to talk of an Irish or Irish-Scottish tradition, Kelvin did have distinct reservations about science as carried out in Cambridge and London (and his allies showed some contempt for what was carried out at Oxford). It may be suggested that Kelvin established and led a tradition that flourished in particular in the industrial cities of Glasgow and Belfast. Though the social position of Fitzgerald and the architectural splendours and ancient traditions of TCD may seem much closer to Oxbridge than to industry, Weaire [36] suggests that, frustrated by the lack of interest in applied science in Dublin, “He might have been happiest in Belfast among the linen factories and shipyard cranes of the Lagan, looking across to the Clyde,” so, to that extent, we may add in some aspects of work in Dublin and create an Irish-Scottish tradition centred mainly, though not necessarily exclusively, on Kelvin himself. The suggestion will have much in common with that of Crosbie Smith [29], but may be somewhat wider in scope than his “energy physics”, and will be more open to consideration of the Irish element, as discussed for many of those already mentioned, as well, of course, for the importance of the upbringing of Kelvin and his brother.

Aspects of this tradition may include working on problems of practical importance, being prepared to interact with engineers and industrialists, and actually tackling engineering and design problems. It may also include a willingness to tackle major syntheses, and to discuss the fundamental or theological significance of these syntheses, even perhaps to make use of religious metaphor or mental constructs in the creation of these syntheses. However we will not insist on the view of religion necessarily being positive; it is the interest that is relevant.

We may explore these factors in the context of some of Kelvin’s most important work. We will start with his work on what today might be described as potential theory, the relationship between charge density, field and potential, which may be described as the basis of electrostatics, but is also relevant to many other areas of physics, the electrostatic charge being analogous, for example, to the mass in gravitational theory. Kelvin was extremely young at the time, at the beginning of the work an undergraduate and at its conclusion a relatively fresh postgraduate; nevertheless he was coming up with the ideas at the same time as, and in some ways surpassing, such mathematical greats as Gauss and Sturm; as it transpired they were all broadly repeating largely unknown work performed over a decade earlier by George Green (figure 75) [87]. It might be said that Kelvin was working within the Cambridge tripos tradition of applying mathematics to physical problems, but perhaps already extending the tradition beyond the more standard topics of mechanics and planetary motion.

The second area where Kelvin’s work was of tremendous significance was electromagnetism. It is, of course, well-known that Maxwell was responsible for the laws of electromagnetism, an achievement which has ensured his fame lasting into the twenty-first century. Almost as well-known is the fact that Kelvin rejected its final form; he opposed in particular the inclusion of the displacement current, but also the duality of vectors – $E$ and $D$ for the electrical vector, $B$ and $H$ for the magnetic. This failing has caused Kelvin’s reputation to drop significantly. Yet the irony is that Maxwell’s work was built so comprehensively on foundations laid by Kelvin that it would scarcely be unjust for the laws to be called the Kelvin-Maxwell or Thomson-Maxwell laws!

The usual storyline is that Coulomb’s law was the centre of the mathematical approach to electromagnetism, that Faraday rescued the subject from its over-mathematical state with his pictorial representations of fields, and that finally Maxwell put Faraday’s pictures into a more suitable mathematical form. This is certainly not the whole truth, and the missing parts both relate to Kelvin [87].
First, Kelvin was initially highly unimpressed by Faraday’s lack of mathematics, but later came to understand and appreciate his approach. He cleared up some of Faraday’s own misconceptions. (Faraday at first thought that Coulomb’s law meant that lines of force had to be straight, and that the law was therefore disproved by his own experiments; Kelvin explained that theory and experiment were totally in line.) Kelvin then interpreted Faraday’s work for the benefit of Gauss and other prominent mathematical physicists. Faraday and Kelvin interacted fruitfully for the rest of Faraday’s career; indeed, in the work on fields, Kelvin’s role was so significant that historians of science have debated whether Faraday or Kelvin should be regarded as the founder of field theory [88-9].

Secondly, Kelvin taught Maxwell a vast amount about every aspect of electromagnetism, as freely admitted by Maxwell himself [87, 90-91]. And Kelvin’s own analysis, based on the mathematical analogy between heat conduction and electrical attraction, took Maxwell a very long way into his own theory.

Here we are less concerned in deciding why Kelvin failed to take the last step while Maxwell was able to do so, than in recognising that our putative Irish-Scottish grouping, including, of course, both Kelvin and Maxwell, was willing and able to apply advanced mathematical methods to the solution of physical problems, and to tackle major syntheses. In the field of electricity and magnetism, Kelvin also applied theoretical knowledge and experimental ingenuity to the solution of a large number of engineering problems, in particular the Atlantic cable, and put great effort into the establishment of a set of coherent practical units [92].

We now turn to the area where Kelvin is probably best-known – thermodynamics. Here we note that many of the characters involved around Kelvin in this area - Rankine, Tait, James Thomson, Jenkin, and also Maxwell, who, although too young to take part in the fundamental work, made great contributions to the follow-up work of kinetic theory, including, of course, consideration of the so-called Maxwell demon – had strong Irish or Scottish connections, or, interestingly, often both. And certainly the work fulfils our criteria of applying mathematical principles to novel physical topics, and of being willing to tackle major syntheses. Indeed, of the three chief founders of thermodynamics, at least at time of the initial flowering of thermodynamics, Clausius had rather narrow interests restricted largely to heat engines [93], and actually, even among our grouping, the important work of Rankine was mostly restricted to molecular models. In immense contrast, Kelvin’s work was concerned with the most general aspects of science including conservation, irreversibility, the new and all-important quantity of energy, and effectively the whole history of the universe.

With such a wide compass, it was inevitable that theological matters would be included. This is in accord with one of our suggestions for Irish-Scottish science, a willingness, even a desire, to tackle such issues where appropriate, and it was very much to the taste, also, of Kelvin and his brother James. Through the 1840s [2], the brothers were perplexed by matching theological and physical problems. On the theological side, on the one hand they were convinced that God was the eternal and only creator, and that it was unthinkable that human beings could themselves create or destroy. On the other, there was a strong biblical tradition of a decaying creation, of change, irreversibility, dissipation; mountains were eroded, and animals and human beings died. In a draft of his 1851 paper, Kelvin gave a reference to the biblical text from Isaiah 51: 6: “For the heavens shall vanish away like smoke, and the earth shall wax old like a garment.”

On the physical side, though Newton had believed that there was a requirement for God to maintain the solar system in its many rotations, at least by the beginning of the nineteenth century it would have been practically taken for granted that the motion of the universe was self-sustaining and there would be no ‘winding down’. However in 1833 the discovery that Encke’s comet was slowing down suggested that there was a resistive medium in the universe, which would eventually bring all motion to a halt, along, of course, with all life.

The brothers were particularly puzzled by the fact that sometimes effort or the burning of fuel produced useful results in the form of work achieved, suggesting some kind of conservation law, but sometimes not. On a canal, the lock-keeper’s effort in raising water may have the useful result of raising the level of the boat; sometimes, though, the water may just cascade over the top of the lock,
the effort apparently being wasted. Similarly burning of coal or oil will provide a hot reservoir which may be used to obtain useful work using an engine; however the heat from the reservoir may also be transferred straight to a cold reservoir by conduction, with no work produced.

The brothers’ puzzles were resolved in the two laws of thermodynamics, produced by Clausius in 1850 and independently by Kelvin in 1851 (Rankine’s contributions being highly significant also). The first related directly to conservation of energy. The second said that, though energy was always conserved, it could be rendered unavailable or ‘lost in the material world’ in the form of low temperature heat which could not be used to do useful work. This second law thus gave irreversibility in nature, dissipation of energy, an arrow of time, and the possibility of an eventual ‘heat-death’ when all energy will have been downgraded to heat.

It was Kelvin and Tait in *T and T’* [16] who took on the task of announcing and promotion of the energy paradigm, which provided a new approach to the structure of physical law, largely replacing the older Newtonian paradigm with its emphasis on force and acceleration. In their hands the new synthesis, based on the Laws of Thermodynamics, had the result that physics became, almost by definition, the science of energy. (It may be mentioned that Clausius did not take up the idea of energy until the 1860s, though at that time, as already mentioned, he did introduce the very important quantity of entropy, extremely useful for discussion of the irreversibility of the universe, and indeed the basis of an interesting and important re-statement of the Second Law of Thermodynamics [93].) Thermodynamics was, of course, the basis of many inventions, and, of the Irish-Scottish group, James Thomson and Rankine were particularly involved in the design of new engines [29].

We have seen some of the features of Kelvin’s important work, and have suggested how these features might be generalised to some of the putative Scottish-Irish group of scientists and engineers. It is interesting to wonder how much further one might take the argument. For example, for all the mutual antipathy between Kelvin and his friends on the one hand and Tyndall on the other, if, as we have said, one of the criteria of membership is applying ideas concerning religion to science, one might say that Tyndall’s negative views on religion are as important in his approach to science as the positive views of Kelvin. Thus it may seem possible, reluctantly or otherwise, to include Tyndall.

Stokes, of course, has a foot in both the Irish and the Cambridge camps. He was intensely interested in the relation between religion and science, but it might be said that ideas on religion did not actually play a role in his construction of theories. He seems also to have been also less willing to attempt to construct large-scale syntheses than some members of the group, more willing to stick to the solution of individual problems. McMillan [28] has also pointed out that Stokes did not charge for his advice, for example, to the Grubbs, in rather a contrast to Kelvin, who was convinced of what may be called the Presbyterian doctrine that one should do good work, and where appropriate give no apology for being well paid for it. Indeed, for all their closeness it must be remembered that Kelvin and Stokes were quite different in many ways. One may thus feel inclined to exclude Stokes from our grouping. Consideration of the rest of those mentioned in the first section may be left as an exercise for the reader!

As a last point, we ask the awkward question – should Kelvin actually be regarded as Scottish or Irish? He spent, of course, 75 years in Scotland, but his roots and early upbringing were in Ireland. Indeed in the Home Rule crisis, described by Iain Hutchison in this volume [94], he always claimed he was speaking “as an Irishman”, and also spoke of “my beloved Ireland”. It is here suggested that by far the most reasonable answer to our question is that he and his family were Ulster-Scots, in the sense that they were equally at home in the North-East of Ireland and the South-West of Scotland. It was natural for his forbears to have travelled from Scotland to make their home near Ballynahinch. Equally it was natural for Kelvin’s father to have attended University in Scotland and then to have taken up his position back in Belfast. It was natural for him to have moved to Glasgow after the death of his wife and for academic promotion, but just as natural for his daughter Anna to marry and move back to Belfast with her husband, and to coax her brother James back to Belfast and eventually to his position at QCB. James, of course, was also to move back to Glasgow. Kelvin campaigned for a political position favoured in particular in the North-East of Ireland (although he himself would not
have argued for a separation between the various parts of Ireland; he was no advocate of partition), his area of campaigning being the South-West of Scotland.

Particularly after the death of his long-term invalid first wife and when he had purchased the ocean-going yacht, the *Lalla Rookh*, Kelvin frequently used it to travel to Belfast and its surrounding region. He might have planned a scientific discussion, perhaps with Thomas Andrews; maybe some planning of a technological development in Ireland; possibly in the appropriate period a time of political plotting, berating the perceived wickedness of the Home Rulers; and not least a meeting with members of his family.

Glasgow and Scotland doubtless have an excellent claim to regard Kelvin as one of their own; there is no reason why Belfast and Ulster may not do just the same.

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