Pioneers of Science Education: #12
John Tyndall (1820-1893) Blue skies researcher and inspired lecturer

Peter E. Childs
Emeritus Senior Lecturer, Department of Chemical Sciences, University of Limerick, Limerick
peter.childs@ul.ie

Introduction:

Figure 1: The young John Tyndall (Tyndall National Institute - John Tyndall**)**

In 2020 we celebrated the centenary of the birth of John Tyndall, the Carlow man who became one of the most well-known and controversial scientists of the 19th century. He was noted as an outspoken atheist, a friend of Thomas Huxley (PoSE #5) and succeeded Michael Faraday at the Royal Institution in London. The two men could not have been more different Michael Faraday was a self-educated, self-effacing Christian believer and Tyndall was well educated, a polemicist and an outspoken materialist. But Tyndall had the greatest respect for Faraday and said of him:
"Taking him for all and all, I think it will be conceded that Michael ***Faraday*** *was the greatest experimental philosopher the world has ever seen."*

John Tyndall is famous for his scientific contributions to physics, atmospheric science, glaciers and the environment (see below), but in this article I want to focus on his educational contributions. He was one of the group of scientists in England, clustered around Thomas

Huxley, members of the X club, anti-organised religion, who were determined to carve out a major role of science in the contemporary educational scene, then dominated by the classics and religion. Together they had a massive influence on how science education developed in England, especially in second level schools, something which continues to this day.

Early life and education

John was born on August 2nd 1820 to John Tyndall and Sarah Macassey, in the little village of Leighlinbridge, Co. Carlow. Only one other child, Emily, survived childhood. The family originally came from Northumberland in England, and the bible translator William Tyndale was a distant ancestor. His father was a shoemaker but became a policeman and was moved around Ireland. His father was a staunch Protestant and an Orangeman and encouraged John in religious debate,as well as inculcating a love of nature. They came back to Leighlinbridge and John attended local schools. When he was 16 he was taught by John Conwill at the National School in Ballinabragh, where he received an excellent education in mathematics - algebra, geometry, trigonometry and conic sections – which stood him in good stead in later life. He would seem to have had a gift for mathematics and was able to visualise spatial relations without models. He doesn't seem to have any formal science education. Aged 19 in 1840, John left school and joined the Ordnance Survey, where he learned the additional skills of draughtmanship and surveying. He worked first in Carlow, then in Youghal, and was transferred to Preston in England in 1842. He enrolled at the Mechanics Institute, which were then a major vehicle for lifelong education and there he became interested in science. In 1843 he, and other colleagues, were dismissed for making a public protest about working conditions. He then joined a company of railway engineers, as it was then the height of the 19th century railway boom, and his mathematical and surveying skills made Tyndall very employable. For some reason he gave up a well-paid job in 1847 and took a post to teach mathematics at Queenwood College, Hampshire. This was to prove a major turning point in his life.

Table 1 Chronology of Tyndall's life

1820	Born 2nd August to John Tyndall and Sarah Macassey, Leighlinbridge, Co. Carlow
1839	Joined the Ordnance Survey (O.S.) – Carlow, Youghal,
1842	Moved to the O.S. Preston
1843-47	Surveyor with a railway engineering company
1847-48	Teacher at Queenwood College, Hampshire
1848-51	Marburg, Germany PhD under Robert Bunsen
1851-53	Teacher, Queenwood College
1852	Elected FRS
1853-87	Professor Nat. Phil., Royal Institution
1859-68	Professor Nat. Phil., Royal School of Mines
1864	Rumford Medal, RS
1869	Founding group, *Nature*
1874	BAAS, Belfast address
1876	Married Louisa Hamilton (1845-1940)
1887	Retired
1893	Died 4th December – accidental poisoning

Tyndall as a teacher

Tyndall had two periods teaching at Queenwood College, a pioneering Quaker college in Hampshire (Figure 2). There he met the chemist Edward Frankland and they became life-long friends and colleagues. Tyndall was hired to teach maths but while there picked up science, learning chemistry from Frankland. The article by Thompson (1957) gives a good introduction to this period.

Figure 2: Queenwood College, Hampshire

Queenwood College had been founded by the social entrepreneur Robert Owen in 1839 as Harmony Hall, focusing on agriculture, but it closed as a community in 1845, after trying to run a school for two years. In 1846 it was bought by the Quaker George Edmondson and reopened as a school in 1847 (Thompson, 1955) specialising in vocational education, and with a science bias. Edmundson had previously run schools successfully in Blackburn and Preston, but saw Queenwood as an opportunity to include agriculture in education as it had an 800-acre farm on site. Queenwood was an experimental public, fee-paying school, based in part of Pestalozzian principles, and it lasted until 1896. Edmondson explained his philosophy:
"Schools and colleges seldom do more than afford opportunities for the acquirement of knowledge; for its right application and lasting retention, they scarcely profess to make any provision. Our pupils' progress will be tested by their ability, and not by their amount of knowledge. So far as is possible, everything will be taught, and learned among us, practically, that is with a view to the business of life."(Quoted in Thompson, 1957, p. 41)
The school was very modern and progressive in its mission statement.
"To give an education in harmony with the age, an education that shall combine practice with theory and assimilate, as far as possible, the occupations of a college with those of real business, and thus fit a youth to fill and adorn the position in life he is to achieve and maintain."(Quoted in Thompson, 1957, p. 41)

It was the first time that experimental science was taught practically in am English school, using the laboratory and the outside world, and predating the work at Rugby by Wilson (PoSE #4) and Br. Burke in Cork (PoSE #6). The students and staff produced newspapers,

and boys were encouraged to research and present papers on current topics, often of an applied nature. The teaching and practical work and examinations all reflected a practical bias towards the application of science.

Frankland had come back to England after studying under Bunsen in Marburg, Germany and no doubt imported the German method of hands-on teaching through research. Frankland taught Tyndall chemistry and Tyndall taught Frankland mathematics. Frankland afterwards said of Tyndall: *"He was a splendid teacher, his aim being to make you think for yourself instead of merely committing things to memory."* (Quoted in Thompson, 1957, p. 42) At this time Tyndall knew almost no science and so he attended Frankland's lectures along with the boys, and soon was teaching science as well as mathematics. This anecdote from Thompson (1957, p. 42) gives a flavour of the exciting environment in Queenwood at that time. *"The boys at Queenwood, unlike their counterparts in the public schools, learnt their science in the laboratory and lived in a thorough atmosphere of research. On one occasion Tyndall and Frankland experimented on themselves with anaesthetics. Tyndall lost consciousness under the influence of ether, while 'a blissful state of inebriation' was induced in Frankland."*

Tyndall, despite his lack of experience, was a success as a teacher, who never forgot he had been young and ignorant himself. In a letter he said: *"As an educator I have myself been educated far less by contact with my colleagues, than by a contact with the lads."* (Thompson, 1957, p. 43). Herbert Spencer extolled Tyndall's teaching methods: *"He not only took care to set forth truths in such ways and in such order, that the comprehension of them developed naturally in the minds of those he taught – he did more; he practised those minds themselves in constructive imagination. He did not, like most teachers, make his pupils mrere passive recipients, but he made them active explorers."* (Quoted in Thompson, 1957, p. 43)

A number of distinguished scientists were to teach at Queenwood over the years, starting with Edward Frankland (Chemistry) and John Tyndall (Mathematics), and later Heinrich Debus, Arthur Hirst, Robert Galloway and William Barrett, all later professors in universities. (Thompson, 1955)

No doubt under the influence of Frankland, and despite having made a success of teaching, Tyndall saved up enough money to make the pilgrimage to Marburg and both he and Frankland travelled to Germany in October 1848. Tyndall had to learn German, as well studying Mathematics, Physics and Chemistry, working for sixteen hours a day. His hard work paid off and he finished his PhD in two rather than three years, and was thus able to devote the third year to research. He returned to England for good in June 1851, having paid a short visit back to England from June-October 1850, during which time he met Faraday. In July 1851 he submitted four papers for the BAAS meeting in Ipswich and in 1852 was elected a Fellow of the Royal Society, a singular honour at his age. Based on his scientific work to date, he would not have been elected FRS today, but they had a policy then of encouraging young researchers, and Tyndall certainly repaid their trust, publishing over one hundred and forty scientific articles. Dr Bence Jones of the Royal Institution (RI) travelled to Germany in late 1851 and heard about Tyndall's work, and consequently invited him to give an evening discourse at the RI on February 11th 1853, at which Faraday was present. The lecture was a great success, despite Tyndall's nervousness, and decided Tyndall's future career in science.

Tyndall at the Royal Institution (RI)

It could be said, not unfairly, that Tyndall's friendship with Michael Faraday determined the main course of his scientific career. Tyndall's first scientific work was on diamagnetism, first identified by Faraday, and they bonded over this interest. The very successful evening discourse at the RI mentioned above, led to Tyndall being appointed as Professor of Natural Philosophy in 1853. He remained at the RI for the rest of his career until he retired in 1887. His initial brief at the NI was to give 19 lectures a year and conduct research, and over the years he gave hundreds of public lectures. At the same time, as was common, he also held a professorship in natural philosophy at the Royal College of Mines in Jermyn Street from 1859-68.

Figure 3: Tyndall lecturing at the Royal Institution

At the RI, Tyndall developed his gifts for clear exposition, aided by simple demonstrations, of scientific ideas, following the tradition of Humphry Davy and Michael Faraday (Figure 3). These lectures were not part of a formal course of study, as they would be at a university, but were designed for the intelligent lay person.

"Almost from the moment he arrived in London, Tyndall became an evangelist for the cause of science. His experience in Germany had convinced him that traditional British education, with its emphasis on the classics and rote mathematics, was hopelessly outdated and detrimental to the good of the country. Thus, his lectures at the Royal Institution were not merely to entertain or even to instruct his audience, but to awaken them to the beauty and importance of science." (Burchfield, 1981, p. 6)

The RI lectures attracted enormous crowds from fashionable society, men and women, people of social standing but without any formal scientific education. Today we would call Tyndall a popularizer of science, similar to his friend Thomas Huxley (PoSE #5), and if he were alive

today, he would undoubtedly be a media star on television. Oliver Lodge wrote this account of Tyndall as a lecturer, but rather damning him with faint praise.
"His knowledge of physics was picturesque and vivid rather than thorough and exact, and never did it make any pretence at being encyclopaedic. In amount it did not much exceed what any highly educated man of genuine all-round culture should aim at, though it was far in excess of what in England is thought possible; but its vividness and colour and garnish of enthusiasm were his own. His strong picturesque mode of seizing and expressing things gave him an immense living influence both in speech and writing, and disseminated a popular knowledge of elementary physics such as had not previously existed .. In his power of exposition to the unlearned he far excelled all his contemporaries, not has there been another like him with his peculiar power of catching the popular imagination and riveting his attention. But one reason for his success was that he never tried to expound anything especially recondite – he never hesitated to elaborate the simple and illustrate the easy so that persons unaccustomed to scientific conceptions of any kind were able by his aid to experience the novel sensation of really comprehending something in a region perfectly new *– a fact which fully accounts for the great popularity of his lectures and books."* (Lodge, 1902)

Tyndall had a great admiration and affection for Michael Faraday, which was reciprocated. Tyndall said of Faraday:
"The contemplation of Nature, and his own relation to her, produced in Faraday, a kind of spiritual exaltation which makes itself manifest here. His religious feeling and his philosophy could not be kept apart; there was an habitual overflow of the one into the other." Tyndall repaid the support he received by his life-long devotion to Faraday, reflected in his book *Faraday as a discoverer* (1868). This book is still in print and available free online (Figure 4).

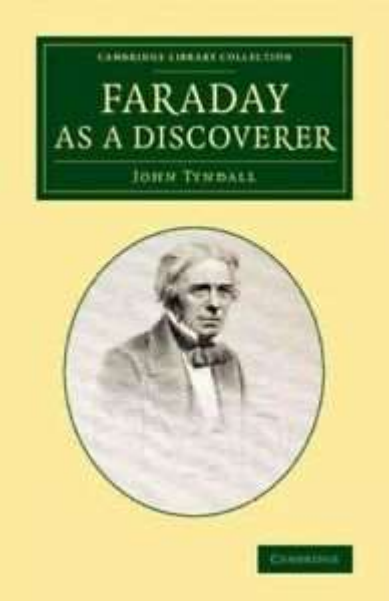

Figure 4: Cover of *Faraday as a Discoverer* (CUP)

Also, like Huxley, Tyndall was a prolific writer of books and essays (Table 2), often turning his lectures into books, and he helped found the influential journal *Nature* in 1869.

Table 2: Books by John Tyndall

(1860), The glaciers of the Alps, Being a narrative of excursions and ascents, an account of the origin and phenomena of glaciers and an exposition of the physical principles to which they are related, (1861 edition) Ticknor and Fields, Boston
(1862), Mountaineering in 1861. A vacation tour, Longman, Green, Longman, and Roberts, London
(1865), *On Radiation: One Lecture* (40 pages) [81]
(1868), Heat : A mode of motion, (1869 edition) D. Appleton, New York
1869), *Natural Philosophy in Easy Lessons* (180 pages) (a physics book intended for use in secondary schools)
.(1870), Faraday as a discoverer, Longmans, Green, London
(1870), *Researches on diamagnetism and magne-crystallic action: including the question of diamagnetic polarity*, Longmans, Green, London
(1871), Hours of exercise in the Alps, Longmans, Green, and Co., London
(1871), *Fragments of Science: A Series of Detached Essays, Lectures, and Reviews*, (1872 edition), Longmans, Green, London
(1872), *Contributions to Molecular Physics in the Domain of Radiant Heat*, (a compilation of 1860s research reports), (1873 edition), D. Appleton and Company, New York
(1873), The forms of water in clouds & rivers, ice & glaciers, H. S. King & Co., London
(1878), Sound; delivered in eight lectures, (1969 edition), Greenwood Press, New York
(1882), Essays on the floating matter of the air, in relation to putrefaction and infection, D. Appleton, New York
(1887), Light and electricity: notes of two courses of lectures before the Royal institution of Great Britain, D. Appleton and Company, New York

His post at the RI gave Tyndall many advantages in his scientific career, as it really was the plum job in science at the time. It gave him access to a well-equipped laboratory and funds for research; it gave him personal financial security; it gave him the opportunity and a platform to develop his presentation skills; it gave him social cachet, enhanced when he married into the aristocracy; and above all he had Faraday as a colleague, mentor, role model and inspiration. He worked closely with Faraday and eventually took over his mantle as Superintendent and then Director of the RI.

A sign that Tyndall had arrived socially were the cartoons in *Punch*, the famous satirical weekly, and a caricature in *Vanity Fair* (Figure 5). His angular face and facial hair were a gift to cartoonists, and much like Huxley, was instantly recognisable.

Figure 5: John Tyndall's *Vanity Fair* cartoon

Tyndall also made a successful lecture tour of the United States in 1872-3 and gave the profit from the lectures to fund science education in the States. (Youmans, 1894)

The quotable Tyndall

Though not in the same popularity league as Thomas Huxley, Tyndall often made the popular press with his views on science and religion. Some of his well-known quotes are given below.

"Religion lives not by the force and aid of dogma, but because it is ingrained in the nature of man. ...the moulds have been broken and reconstructed over and over again, but the molten ore abides in the ladle of humanity."

"Discussion, therefore, is one of the motive powers of life, and, as such, is not to be deprecated."

"It is as fatal as it is cowardly to blink facts because they are not to our taste."

"The brightest flashes in the world of thought are incomplete until they have been proved to have their counterparts in the world of fact."

"Religious feeling is as much a verity as any other part of human consciousness; and against it, on the subjective side, the waves of science beat in vain."

"Those who are unacquainted with the details of scientific investigation have no idea of the amount of labour expended in the determination of those numbers on which important calculations or inferences depend. They have no idea of the patience shown by a Berzelius in determining atomic weights; by a Regnault in determining coefficients of expansion; or by a Joule in determining the mechanical equivalent of heat."

"Taking him for all and all, I think it will be conceded that Michael Faraday was the greatest experimental philosopher the world has ever seen."

"A few days ago, a Master of Arts, who is still a young man, and therefore the recipient of a modern education, stated to me that until he had reached the age of twenty he had never been taught anything whatever regarding natural phenomena, or natural law. Twelve years of his life previously had been spent exclusively amongst the ancients. The case, I regret to say, is typical."

"Every occurrence in Nature is preceded by other occurrences which are its causes, and succeeded by others which are its effects. The human mind is not satisfied with observing and studying any natural occurrence alone, but takes pleasure in connecting every natural fact with what has gone before it, and with what is to come after it."

"The first experiment a child makes is a physical experiment: the suction-pump is but an imitation of the first act of every new-born infant."

"With accurate experiment and observation to work upon, imagination becomes the architect of physical theory."

"Behind all our practical applications, there exists a region of intellectual action to which practical men have rarely contributed, but from which they draw all their supplies."

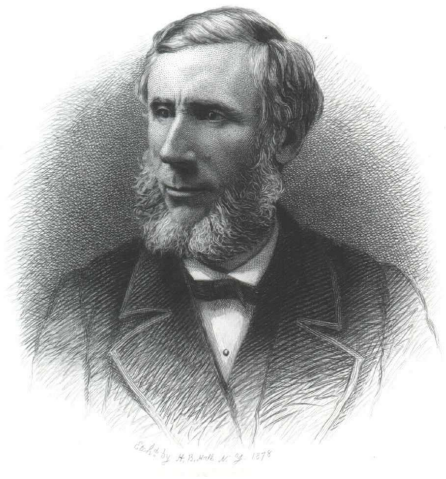

Figure 6: John Tyndall later in life in ca. 1872 (John Tyndall - Wikipedia**)**

Research work

Although he spent most of his adult life in scientific research, following his time in Germany, Tyndall, like Faraday, did not set up a research school and only had one PhD student, unlike Henry Armstrong (PoSE#). Tyndall was a solitary researcher but was very productive because he worked hard. Although he made many important contributions, often building on prior work, he would not be considered in retrospect a first-rate scientist, in the class with Faraday, Kelvin or Maxwell. Tyndall first defined physics as a discipline and coined the word physicist: physics is "that portion of natural science which lies midway between astronomy and chemistry." But as a natural philosopher, Tyndall also dabbled in chemistry and in biology, although most of his investigations would lie within physics. He founded the boundary subject of chemical physics and highlighted for chemists the future importance of photochemistry, the effect of light on chemistry. He did research work on glaciers, on atmospheric chemistry and in bacteriology. He demonstrated the basis of the greenhouse effect and showed how the scattering of light by small particles produces the blue sky, known now as the Tyndall Effect. (See John Tyndall - Wikipedia for a summary of his scientific work.) This was curiosity driven research and the phrase 'blue skies' research was coined in Tyndall's honour. He always stressed the importance of research for its own sake, but his work was to lead to optical fibres, the infra-red spectrometer, a method of preserving food (tyndallisation), and a novel fireman's respirator.

Figure 7: A classic photo showing L to R: Michael Faraday, Thomas Huxley, Charles Wheatstone, David Brewster, and John Tyndall (File:Physiker.jpg - Wikimedia Commons)

Tyndall the controversialist

I cannot leave an article on Tyndall without commenting on his controversial views on science and religion. He and Thomas Huxley were the Richard Dawkins and Peter Atkins of their day, militantly pro-science and anti-religion, in an age suffused with Christianity, where the universities and schools were largely controlled by the Church of England. Tyndall and Huxley were members of the X-club, a dining club for like-minded scientists. (X Club - Wikipedia) This was a group of like-minded scientists which met from 1864 to 1893, which acted as a pressure group to forward the interests of science, united by a *"devotion to science, pure and free, untrammelled by religious dogmas."*

Tyndall's views came to public notice through his long address at the BAAS meeting in Belfast in 1874, which promoted scientific naturalism.

"We claim, and we shall wrest from theology, the entire domain of cosmological theory. All schemes and systems which thus infringe upon the domain of science must, insofar as they do this, submit to its control, and relinquish all thought of controlling it." (John Tyndall, BAAS Belfast address 1874, quoted in Jackson, 2020).

Rather than attacking Christian theology, especially in a religious cauldron like Belfast, Tyndall was trying to argue for a separation of church and state, of theology and science, and that materialist questions should be answered by science, not religious dogma.

"Before the Belfast Address, Tyndall was usually cast in a positive light in the periodical press, albeit with some reservations. He was not labelled as a materialist. But after the

Belfast Address he was portrayed as an aggressive, dishonest, devious, and distinctly un-British materialist." (Lightman, 2011)

Cantor (2015) has re-evaluated Tyndall's religious views, which were more complicated than the various labels atheist, agnostic or pantheist applied to Tyndall suggest. Certainly after the Belfast address Tyndall was seen by many as an atheist and a materialist, and was attacked in the press. He had great respect for Michael Faraday's religious convictions, which Tyndall saw as the mainspring of Faraday's life, and he said of Faraday he *"drinks from a fount on Sunday which refreshes his soul for a week."* In his book, *Faraday as a Discoverer*, published a year after Faraday's death Tyndall wrote:
"The contemplation of Nature, and his own relation to her, produced in Faraday, a kind of spiritual exaltation which makes itself manifest here. His religious feeling and his philosophy could not be kept apart; there was an habitual overflow of the one into the other." (Tyndall, 1868, p. 152)

Conclusion

Tyndall's obsession with mountaineering and glaciers is commemorated with a monument in the Alps and his first books were on glaciers and mountaineering (Table 2).

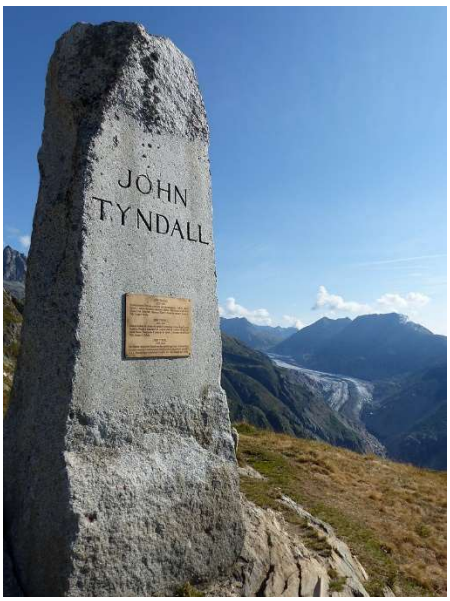

Figure 8: Monument to John Tyndall in the Alps (Tyndall-Denkmal - John Tyndall - Wikipedia)

John Tyndall came from humble stock in a rural part of Ireland, with little formal education, especially in science. We could say he was a self-made man, who made the best of his natural talents and the opportunities presented to him. He rose to the top of 19th century British society, in both social and scientific circles, by a combination of talent and hard work, and was highly regarded in England and abroad. These are some evaluations of his life.
"Tyndall is one of the most intriguing and significant figures of the mid-19th century. The outspoken Irish-born physicist and mountaineer, who rose from a humble background to move in the highest reaches of Victorian science and society, and marry into the aristocracy, is central to the development of science and its place in cultural discourse." (Jackson, 2018)

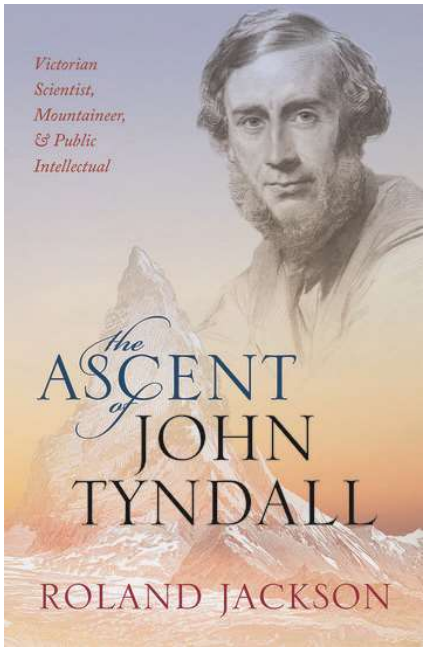

Figure 7: Cover of Roland Jackson's recent biography

"John Tyndall was one of the great public figures of nineteenth-century British science. As a researcher, an educator, a lecturer and a controversialist, he played a major role in the professionalization and popularization of science." (Attis, 2002)

After a long and distinguished 33-year career at the Royal Institution, where he had stepped firmly into Michael Faraday's shoes, he retired in 1887 to Hindhead in Surrey. There his life was cut short when his wife Louisa, accidentally in the dark, gave him chloral rather than milk of magnesia, and so poisoned him. What a tragic and traumatic event that must have been for her. She remained a reclusive widow for the rest of her long life and kept strict control over his letters and papers, always intending to write his biography, but never finishing it before her death in 1940. This meant, that unlike other famous 19th century scientists, no *'Life and Letters'* of Tyndall appeared after his death, and the first biography only came in 1945 (Eve and Creasey, 1945).

"Yet above all else Tyndall thought of himself not as a reformer but as a man of science—and eventually as a physicist. In effect one can identify three main aims in Tyndall's career: first, a desire to carry out original and valuable scientific research; second, a desire to convey the discoveries and ideas of science to the general public; third, a desire to establish science as the predominant cultural authority in Britain." (De Young, 2011, p. 19)

It has been said that Louisa killed him twice, first by poison and second by sitting on his papers for so long. Born in obscurity, his career lapsed into obscurity, and even in Ireland it was not until the 1980s (Brock *et al.*1981*)* that his memory was revived. A new biography (Jackson, 2020, Figure 7) appeared to mark the bicentenary of his birth, together with several articles.

The Tyndall Centre for Climate Research was founded in the UK in 2000. (Tyndall Centre for Climate Change Research |)

In 2004 the Tyndall National Institute was founded at University College Cork. (https://www.tyndall.ie)

In 2020 a new post-primary school in Carlow was named Tyndall College.

Not a bad legacy for a boy from Leighlinbridge, Co. Carlow. So when you see the blue sky and the red setting sun, think of John Tyndall and his blue skies research.

References

Attis, D., (2002), 'John Tyndall', in Charles Mollan, Brendan Finucane and William Davis, eds., *Irish Innovators in Science and Technology*, Dublin: Royal Dublin Society, pp. 127-128

Brock, W.H., Macmillan, N.D. & Mollan, R.C., (1981), *Essays on a natural philosopher,* Dublin: Royal Dublin Society

Burchfield, J., (1981), 'John Tyndall', in *Essays on a natural philosopher*, Brock *et al.* eds., pp 1-13

Cantor, G., (2015), 'John Tyndall's religion: a fragment', Notes and Records, 69, pp. 419-436 Online at John Tyndall's religion: a fragment (royalsocietypublishing.org), accessed 9/4/21

De Young, U., (2011), *A Vision of Modern Science*, London: Palgrave Macmillan.

Eve, A.S. & Creasey, C.H., (1945), *Life and Work of John Tyndall*, London: Macmillan.

Jackson, R. (2018), *The ascent of John Tyndall,* Oxford: OUP.

Jackson, R., (2020), 'Opinion: John Tyndall - the forgotten co-discoverer of climate science', London: UCL News, Online Opinion: John Tyndall - the forgotten co-discoverer of climate science | UCL News - UCL – University College London, accessed 9/4/21

Lightman, B. (2011) "On Tyndall's Belfast Address, 1874." *BRANCH: Britain, Representation and Nineteenth-Century History*. Ed. Dino Franco Felluga. Extension of *Romanticism and Victorianism on the Net*. Online Bernard Lightman, "On Tyndall's Belfast Address, 1874" | BRANCH (branchcollective.org) Accessed 9/4/21

Lodge, O., (1902), 'John Tyndall', *Encyclopedia Britannica*, 10th edition, 33, 517-5121

Thompson, D., (1955), 'Queenwood College, Hampshire: a mid-19th century experiment in science teaching', *Annals of Science*, 11(3), pp. 246-254

Thompson, D., (1957), 'John Tyndall (1820-1893): a study in vocational enterprise', *The Vocational Aspect of Secondary and Further Education*, 9(18), 38-48

Tyndall, J., (1868), *Faraday as a Discoverer*, London: Longmans, Green and Co. Online at Faraday as a discoverer : Tyndall, John, 1820-1893 : Free Download, Borrow, and Streaming : Internet Archive Accessed 9/4/21

Youmans, E.A., (1894), 'Tyndall and his American Visit, *Popular Science Monthly,* Feb. 1894, online at Popular Science Monthly/Volume 44/February 1894/Tyndall and his American Visit - Wikisource, the free online library. Accessed 9/4/21