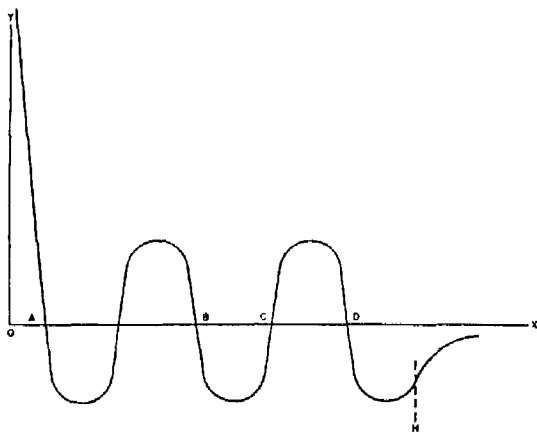


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2. J. Tyndall, *Faraday as a Discoverer*, Longman, Green & Co., London, 1868.
3. J. H. Gladstone, *Michael Faraday*, Macmillan, London, 1872.
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5. S. P. Thompson, *Michael Faraday: His Life and Work*, Macmillan, New York, NY, 1898.
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7. L. P. Williams, *Michael Faraday, A Biography*, Chapman & Hall, London, 1965.
8. M. Faraday, *Experimental Researches in Electricity*, 3 Vols., Quaritch, London, 1839-1855, Vol 3, p. 1.
9. *Ibid.*, Vol. 2, p. 286.
10. *Ibid.* R. J. Boscovich was an 18th-century Jesuit who was a deep student of Newtonian physics. He puzzled over the problem of the collision of the infinitely hard atoms that Newton had suggested in the 31st query of his *Opticks*. Infinite hardness is not compatible with elasticity, so Boscovich insisted that the reversal of motion in a collision would have to be instantaneous, resulting in the absurd notion that the two colliding atoms would each be going in opposite directions at the moment of collision. To solve this problem, Boscovich posited atoms as centers of force, with no material component. The curve below graphs the attractive and repulsive forces associated with such an atom in terms of distance from the atomic center. Forces above the line are repulsive; those below it are attractive. At some distance OA, the force becomes asymptotically repulsive, preventing two points from being in the same place, thus preserving the material property of impenetrability. At H, the attractive force turns into the hyperbola of universal gravitation. Points D and B are stable points for two atoms since the forces will resist displacement; C is an



unstable point since the slightest displacement will cause the particle either to recede from or approach O. It should be emphasized that, for Boscovich, these atoms were fundamental particles and that chemical atoms were compounds of these whose complex patterns of force could be used to account for "elective affinities" and for the regularity of crystals.

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L. Pearce Williams is John Stambaugh Professor of the History of Science at Cornell University, Ithaca, NY 14850 and is author of "Michael Faraday, A Biography" and "The Origins of Field Theory". He has also edited two volumes of "The Selected Correspondence of Michael Faraday".

FARADAY'S ELECTION TO THE ROYAL SOCIETY: A REPUTATION IN JEOPARDY

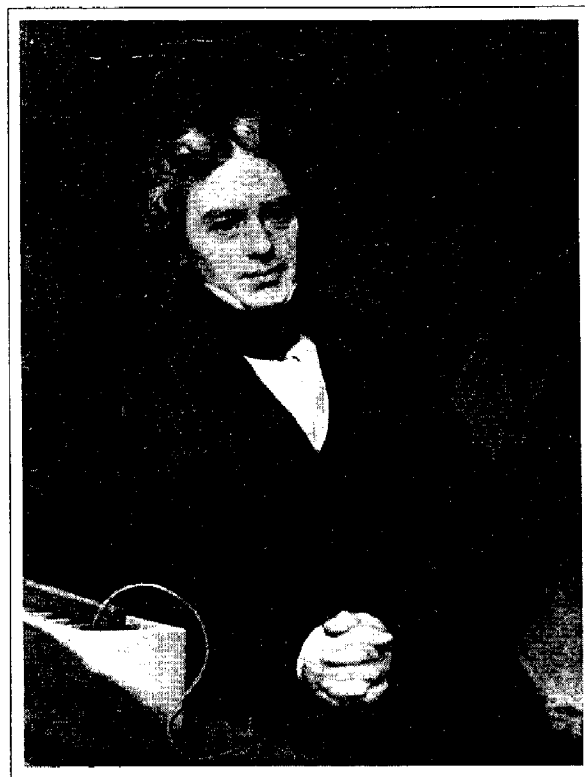
June Z. Fullmer, Ohio State University, and Melvyn C. Usselman, University of Western Ontario

On Thursday, 8 January 1824, the meeting of the Royal Society had, as one order of business, a ballot to elect (or not) Michael Faraday to the Fellowship of the Society. According to established custom, in the absence of the President, Sir Humphry Davy, the Vice President of the Society, Sir Everard Home, presided (1). He was flanked by the two secretaries, William T. Brande and Taylor Combe. After opening formalities, one of the secretaries read the names of those candidates whose certificates for Fellowship had been newly presented. Sir Everard then asked the Fellows if the Society wished to elect these candidates immediately, (certain members of the nobility and other distinguished folk were always accorded "instant" Fellowship - for example, Prince Christian of Denmark on 6 June 1822; Robert Peel, Secretary of State, on 5 December 1822) or ballot for them after their certificates had been displayed over a ten-meeting period. At this juncture Sir Everard announced that the Society would be balloting on the question of Fellowship for Michael Faraday. His certificate had been displayed for the appropriate length of time and had received 29 supporting signatures. After inviting comments from the Fellows about the candidate, Sir Everard demonstrated the ballot-box to be empty before handing it to the Assistant Secretary, John Hudson, who carried it from Fellow to Fellow. Each Fellow registered his vote by choosing either

a white or black marble from one of the attached bags and dropping it into the box. This noisy, disruptive process continued while the Secretary read to the group the learned paper selected for presentation that day. When the ballot box had made its rounds, Sir Everard counted the votes. Faraday's election had been nearly unanimous, there being but a single black ball in the "nay" drawer. Still, the business of making Faraday a Fellow was not yet concluded, for at the next sitting of the Society (15 January 1824), with Sir Humphry Davy, P.R.S., in the chair, Faraday paid his admission Fee "and the usual sum in lieu of Annual Contributions," and "signed the Obligation in the Charter Book". Sir Humphry then shook his hand, and Faraday officially became "F.R.S".

The election result must have been very gratifying for Faraday, for the period preceding the election had been a stressful one. Membership in the Royal Society meant a lot to him, since it certified that he was an accomplished natural philosopher whose researches merited the attention of the world's scientific community. In 1838 when Spring-Rice, Chancellor of the Exchequer, asked Faraday why he had received a pension (granted in 1835) from the Crown, what titles had he? Faraday replied: "One title namely, that of F.R.S., was sought and paid for; all the rest [and there were many] were spontaneous offerings of kindness and goodwill from the bodies named" (2). Faraday's unguarded response shows how distressing the process had been. What price had he paid? What had his fight for recognition of his scientific abilities cost him?

In the early stages Faraday's election had not been a foregone conclusion. During the eight months comprising the ten "regular" meetings of his candidacy, there had been rumors that Faraday's scientific achievements owed much to unacknowledged contemporaries. On 30 May 1823, an angry Sir Humphry Davy had ordered Faraday to remove his certificate. Throughout the period the prevailing sentiment within the Society was to reduce the number of Fellows by restricting the intake of new members (3). Faraday, caught on the cusp of two

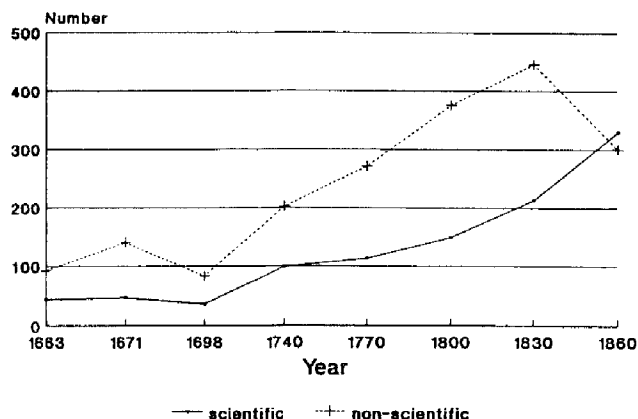


Michael Faraday
(After a painting by T. Phillips)

worlds, one dying, the other struggling to be born, faced genuine threats which forced him into intensive lobbying for votes. By the day of his election, however, his success was assured.

Consider first the atmosphere within the Royal Society. The death of Sir Joseph Banks in June of 1820 provided an opportunity to institute changes within the Society (4). The reformers aimed primarily to make the Society more scientific, chiefly by increasing the proportion of members actively engaged in the sciences and by achieving a stronger voice for those members in the governance of the Society. Quantitative analysis of the composition of the fellowship reveals the magnitude of the problem. As shown in figure 1, total membership in the Society had increased continuously from a low of 119 in 1698 to 659 in 1830 (5). Though the majority of the Fellows were "cultivators" of science, only about 30% of them could be loosely termed "scientific" Fellows (figure 2) (6). In his caustic attack on the Royal Society in 1830, Augustus B. Granville wrote that he could find in the membership only "thirty really illustrious men of science," all the rest being "either mere lookers on - indifferent spectators - or, at most, cultivators of what beds of flowers they found in the rich garden of natural knowledge when they first entered it" (7). Furthermore, during Banks' tenure as president (1778-1820), scientific fellows had always been in a minority on the Council,

FIG.1 ROYAL SOCIETY FELLOWS, NUMBER



whose 21 members governed the Society (figure 3) (8).

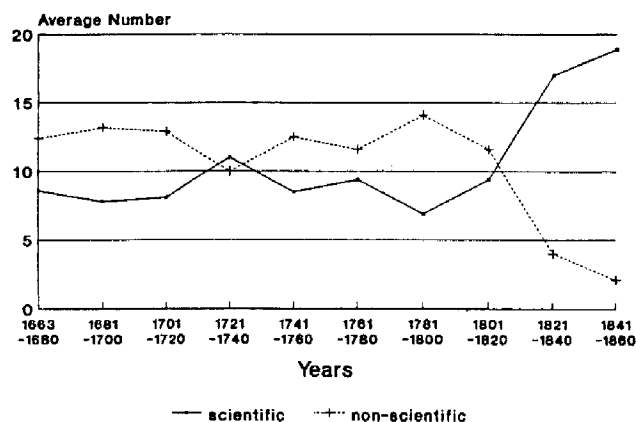
William Hyde Wollaston served as temporary President for the five months of the term which remained after Banks' death; Sir Humphry Davy succeeded him. Davy tried to institute the reforms most wanted by the scientific membership, the group to which he owed the near unanimity of his election (9). The reformers sought to decrease the influx of new members by scrutinizing the scientific credentials of candidates more closely than had been done in the past. If the members were doubtful of a candidate's worthiness, Davy encouraged them to cast negative votes at election time. His recommendation was initially heeded, for the number of new Fellows decreased in 1823 (10). In 1822 John Herschel wrote Charles Babbage that (11):

I think Hamilton had better not be proposed at present. I talked to Davy about him, who of course could have no personal feeling about it and spoke very sensibly on the subject. What he has lately said in the Society has had its full effect ... No ballot I dare say now will pass for a long time without a sharp contest and discussion of the merits of candidates.

Further, Davy had not hesitated to act autocratically when he thought it necessary. After the certificate of Sir Francis Schuckburgh was introduced in December of 1823, Davy wrote at the top, "No qualifications mentioned" and across the bottom, "This certificate ought not to have been presented, there being no qualifications mentioned. H.D." (12). Davy's demand for qualifications could explain why Faraday waited until 1823 before he sought election, for by that time he had published more than 37 scientific papers, three of them in the *Philosophical Transactions* (13). His publication record was explicitly noted in the statement of qualifications accompanying his certificate (14):

Mr. Michael Faraday, a gentleman eminently conversant in chemical science, and author of several papers, which have been published in

FIG.3 ROYAL SOCIETY COUNCIL, MEMBERS



the "Transactions" of the Royal Society, being desirous of becoming a Fellow thereof, we, whose names are undersigned, do of our personal knowledge recommend him as highly deserving that honour, and likely to become a useful and valuable member.

Faraday's worthiness can be further emphasized by comparison with others elected at about the same time. The four persons elected immediately before him were (15):

19 June 1823	Sir John Murray, military general
20 Nov. 1823	John Bayley, antiquary
	Rev. Daniel Creswell, divine and mathematician
27 Nov. 1823	A. Mervin Storey, M.A. (Oxon)

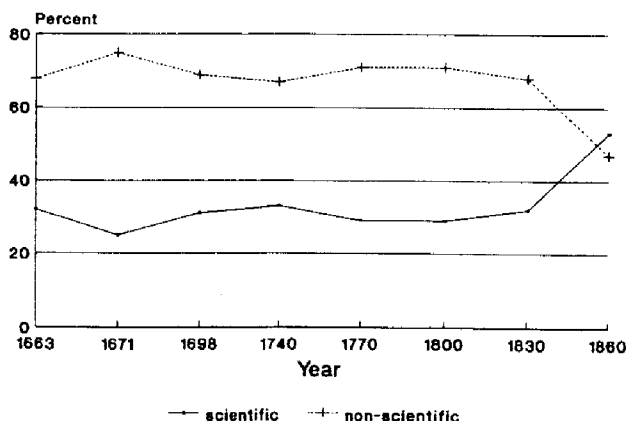
and the four immediately following were:

15 Jan. 1824	Charles Scudamore, physician
22 Jan. 1824	Thomas Amyott, antiquary
5 Feb. 1824	William Wavell, physician
19 Feb. 1824	Rev. Edward Maltby, bishop

Election of such a scientifically undistinguished group illustrated that, whatever the qualifications deemed requisite for successful election, they had not functioned to render many candidates ineligible. To the extent that the reformers within the Society had an impact on the election process, in Faraday's case their efforts would have been positive. Scientific support alone could guarantee election since a large majority of those who regularly attended meetings were science-minded. At least this was true if the science supporters were not themselves divided. Babbage, for one, pointed out how scientific bickering could harm a candidate's chances (16):

... if [a candidate] A. B. had the good fortune to be perfectly unknown by any literary or scientific achievement, however small, he is quite sure of being elected as a matter of course. If, on the other hand, he

FIG.2 ROYAL SOCIETY FELLOWS, PERCENT



has unfortunately written on any subject connected with science, or is supposed to be acquainted with any branch of it, the members begin to inquire what he has done to deserve the honour; and, unless he has powerful friends, he has a fair chance of being black-balled.

There was no evidence of such a split in Faraday's scientific backing, for the 29 signatures on his certificate showed impressive support from natural philosophers, physicians and surgeons (17).

Special importance attached to the first few names on the certificate because they represented Faraday's "proposers" and served as an advertisement of his suitability. Richard Phillips, who sponsored Faraday's application and arranged for the opening signatures, wrote with delight to Faraday shortly after the certificate was first hung: "Did it well I think - Wollaston, Children, Babington, Herschel" (18). In his reply, Faraday indicated his approval (19):

A thousand thanks for your kindness - I am delighted with the Names - Mr. Brande had told me of it before I got your note and thought it impossible to be better.

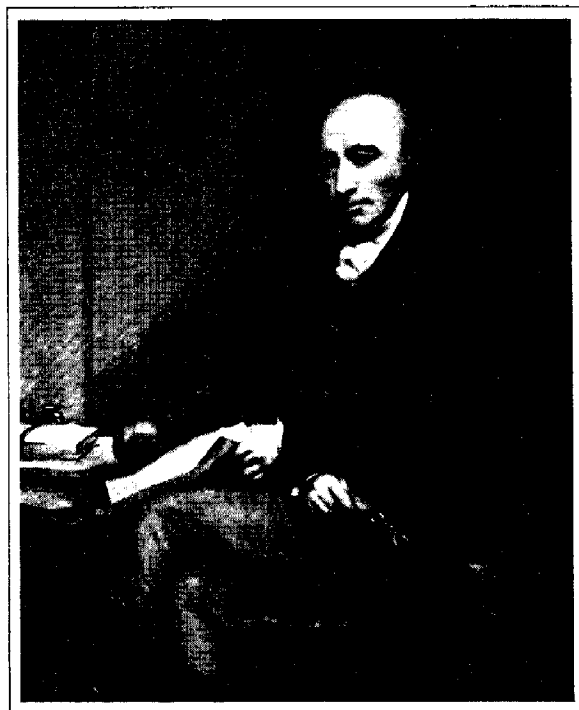
The four leading sponsors represented different constituencies in the Royal Society: John G. Children, whose job at the British Museum owed much to Davy's support, was Davy's long-time friend; Dr. William Babington was a member of the "old guard" of the Society who viewed reform with suspicion, and John W. Herschel was the most highly-regarded of the younger, reform-minded Fellows.

Wollaston's name at the head of the list served two important purposes. He had been President for a short period in 1820, and he was widely admired among the scientific Fellows for his support of reform, his scientific achievements, his intellect and his independence. Nearly Davy's equal in international stature he had, in fact, been the reformers' first choice as successor to Banks. Wollaston championed individualism and readily admired ability in others. His name had also been first on John Dalton's certificate (Dalton, like Faraday a non-conformist, had been made a Fellow in March 1822). Above all, Wollaston's prominent support laid to rest any suspicions that ill feelings remained from the Wollaston/Faraday misunderstanding over the discovery in 1821 of electromagnetic rotation.

On the final day of his interim presidency in 1820, Wollaston had delivered the discourse which accompanied the awarding of the Society's Copley Medal to Hans C. Oersted for his discovery of electromagnetism. In the oration, Wollaston praised the discovery with presidential grandiloquence (20):

... by the very important researches of Professor Oersted, a very intimate relation is established between electricity and magnetism.

Let us hope that the gleam of light which thus beams upon us may be the dawn of a new day in which the clouds that had hitherto veiled from our sight the hidden mysteries of light and heat, of electricity and



William Hyde Wollaston

magnetism, may be dispelled, that the real nature and relation of these imponderable agents may be revealed to us, that truths most important to the advancement of natural knowledge may burst forth in public splendour and complete the series of wonders that we have lived to witness.

Extending Oersted's ideas, Wollaston concluded that the magnetic power of an electric current acted "circumferentially round its axis," and thus a current-carrying wire might be made to spin about its own axis under the influence of an external magnet (21). In April 1821, he and Davy tried unsuccessfully to achieve the predicted result at the Royal Institution. A few months later, and quite independently, Faraday discovered a way to effect electromagnetic rotation; he sent the results for publication in October 1821 (22). Shortly thereafter, Faraday began to hear rumours that he had failed to acknowledge Wollaston's contributions.

The details of the drama that ensued are presented elsewhere; its denouement was important (23). Faraday had been accused of stealing Wollaston's ideas, but Wollaston himself believed Faraday to be innocent of any wrong-doing, for he wrote to Faraday (24):

Sir - You seem to me to labour under some misapprehension of the strength of my feelings upon the subject to which you allude.

As to the opinions which others may have of your conduct, that is your concern, not mine; and if you fully acquit yourself of making any incorrect use of the suggestions of others, it seems to me that you have

no occasion to concern yourself much about the matter.

Ultimately, Henry Warburton, the man chiefly responsible for the whispering campaign against Faraday, was swayed to make an explicit promise to repair any damage that may have been done. A few weeks after Faraday's certificate had been posted, Warburton wrote him (25):

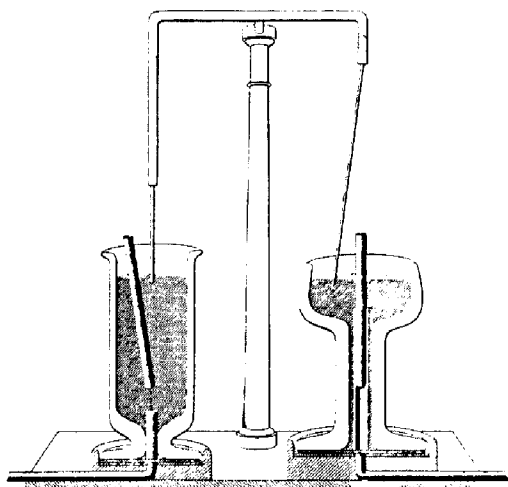
Sir, I have read the article in the "Royal Institute Journal" (vol. XV, p. 288) on electro-magnetic rotation; and without meaning to convey to you that I approve of it unreservedly, I beg to say that, upon the whole, it satisfied me, as I think it will Dr. Wollaston's other friends.

Having everywhere admitted and maintained that on the score of scientific merit you were entitled to a place in the Royal Society, I never cared to prevent your election, nor should I have taken any pains to form a party in private to oppose you. What I should have done would have been to take the opportunity which the proposing to ballot for you would have afforded me to make remarks in public on that part of your conduct to which I objected. Of this I made no secret, having intimated my intention to some of those from whom I knew you would hear of it, and to the President himself.

When I meet with any of those in whose presence such conversation may have passed, I shall state that my objections to you as a Fellow are and ought to be withdrawn, and that I now wish to forward your election.

Warburton could easily enough change his mind, but it took much effort to undo the damage his accusations had wrought. We know that Davy had been moved, likely by Warburton, to oppose Faraday's election. In notes appended to a copy of a letter to Warburton, Faraday wrote (26):

1823. In relation to Davy's opposition to my election at the Royal Society



Faraday's apparatus for demonstrating the existence of "electromagnetic rotation".

Sir H. Davy angry, May 30.

Elsewhere, Faraday had been more explicit (27):

Sir H. Davy told me I must take down my certificate. I replied that I had not put it up; that I could not take it down, as it was put up by my proposers. He then said I must get my proposers to take it down. I answered that I know they would not do so. Then he said, I as President will take it down. I replied that I was sure Sir H. Davy would do what he thought was for the good of the Royal Society.

Bence Jones, in his biography of Faraday, reported that (28):

Faraday also said that one of his proposers told him that Sir H. Davy had walked for an hour round the courtyard of Somerset House, arguing that Faraday ought not to be elected.

While it is not possible to say precisely what transpired, it is possible to determine one catalyst for Davy's anger by examining Faraday's activities after the quarrel, to see who had to be pacified. Since Faraday noted that Davy reproached him on 30 May, it appears likely that Warburton had spoken to Davy about Faraday's candidacy at the meeting of the Royal Society on 29 May. In his letter to Faraday on 8 July, Warburton allowed that he had read Faraday's paper, which recounted why Faraday had not acknowledged Wollaston's work on electromagnetic induction in his two publications of October and December, 1821. Thus Warburton learned that in 1821 Faraday had taken his first paper on electromagnetic induction to Wollaston, prepared to ask him for permission to refer to his work - at the time unpublished - but had not found Wollaston at home. For the second paper he was able to get in touch with Wollaston, who had by then witnessed some of Faraday's newest experiments. Faraday asked Wollaston if he could refer to his work "in correction of the error of judgment in not having done so before." Wollaston's view, as Faraday recalled it, was as follows (29):

The impression that has remained on my mind ever since (one-and-twenty months), and which I have constantly expressed to everyone when talking on the subject, is that he wished me not to do so. Dr. Wollaston has lately told me that he cannot recollect the words he used at the time; that as regarded himself his feelings were it should not be done, as regarded me, that it should, but that he did not tell me so. I can only say that my memory at this time holds most tenaciously the following words, 'I would rather you should not;' but I must of course have been mistaken.

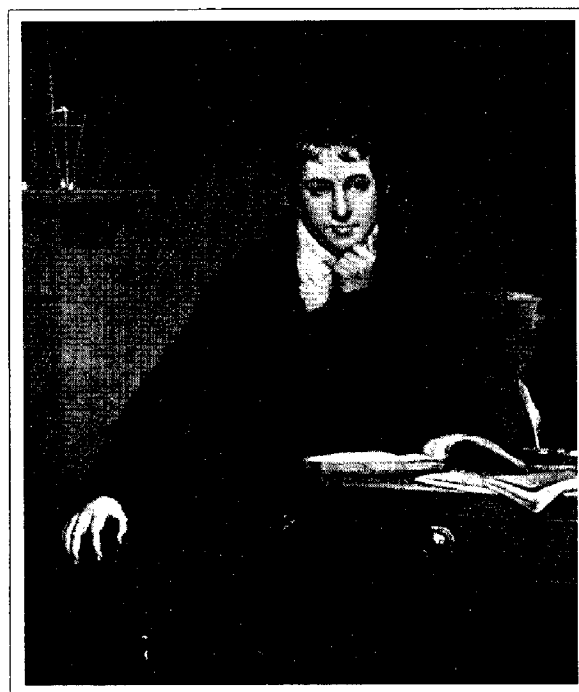
This published acknowledgment of Wollaston's cooperation evidently mollified Warburton. It may even have caused him to regret questioning Faraday's integrity, or at least to rue carrying those doubts to Davy, for Davy could not help but be offended by criticisms of his colleague. Every project on

which Faraday had worked had Davy's blessing: at times the two men had worked side by side; at other times Faraday undertook experiments at Davy's behest. In addition, Davy patently groomed Faraday for Fellowship (as he had groomed his younger brother, Dr. John Davy, in much the same way) by suggesting avenues for his research, by editing his papers before they were to be read and published, and by frequently sponsoring Faraday's attendance at Royal Society meetings. His protégé was in danger of being publicly accused of appropriating another's scientific ideas. Moreover, that accusation would come from a man with power in the Royal Society, a Council member who had much preferred Wollaston over Davy as President.

Davy had wanted the Presidency as badly as Faraday had wanted to be a Fellow. To gain that office, Davy had personally solicited votes and had ardently promised reform of the Society to Wollaston and his supporters. He was working very hard at the tasks reform required, with the result that his time for experimenting was limited. Now he was faced with the possibility that Warburton would rise before the entire group and in a bitter speech heap calumny on Faraday, and through him, on Davy. The only certain way to prevent that from happening was to insure that Faraday not come up for election. This could be done simply by removing Faraday's certificate. Perhaps, after Warburton had suggested that Faraday lacked the moral character required of Royal Society candidates, Davy's well-known temper transformed a minor irritant into major confrontation. John Herschel, for example, had opposed Davy's bid for the presidency of the Society in 1820 on the basis of perceived weaknesses in Davy's character (30):

The reasons for wishing that Davy should be opposed are grounded solely on his personal character, which is said to be arrogant in the extreme, and impatient of opposition in his scientific views, and likely if power were placed in his hands to oppose rising merit in his own line ... [for example] Davy, in consequence of Berzelius's repugnance to admit his views on the simple nature of chlorine was so personally incensed at him, as to exert all his influence (& with success) to procure his rejection, when proposed, during his stay in England [Jun-Nov, 1812] as an honorary Member of ye R.I.

Davy's antipathy toward Berzelius soon passed, however, and his signature was the first on Berzelius's certificate for election as a Foreign Member of the Royal Society (first read 26 November 1812). It is not improbable that his opposition to Faraday's candidacy evaporated just as quickly. After Faraday told Davy on 17 June that Wollaston had been consulted and had not contested Faraday's priority, Davy's anger appears to have dissipated. On 29 June, Davy, in a note to Faraday, hoped he would have "health and success during the summer"; he signed it, as he always had before, "very sincerely your friend and well-wisher." On 23 July he signed another note to Faraday, written in great haste, "your sincere friend."



Humphry Davy

On 28 July, when he had reason to write again, he signed himself "I am Dear Mr. Faraday/very truly your friend &/well wisher" (31).

Perhaps Davy's anger was fueled by uncertainties he himself held about Faraday's conduct in their complementary researches on the liquefaction of gases. In the spring of 1823, when Davy was out of town on his annual fishing trip, Faraday took advantage of the cold weather and some free time to work "upon frozen chlorine," which he said represented a "favourite object" for his research. He used as his starting material chlorine hydrate, a substance Davy had earlier identified as a compound. When Davy returned he asked Faraday what laboratory work he had in hand. Upon hearing Faraday's account, Davy suggested to him that he try heating the solid in a closed tube. He did not tell Faraday what he expected to be the outcome. On carrying out Davy's suggestion, Faraday, somewhat to his amazement, found an oily yellow liquid produced. He repeated the experiment, now using a sealed, "bent" tube. He was able to distill the liquid to one end and subsequently identified it as liquid chlorine. Dr. John Ayrton Paris, present when Faraday first performed the experiment, reported in his biography of Davy that he told Davy at dinner that evening about the puzzling appearance of the liquid (32). Paris' account, in addition to suggesting that Faraday left to his own devices would have been led to make the experiment on his own, also insinuated that Sir Humphry was a liar (33):

Upon mentioning the circumstance [the disappearance of the yellow

liquid from the closed, bent tube when it was cut open] to Sir Humphry Davy after dinner, he appeared much surprised; and after a few moments of apparent abstraction, he said "I shall enquire about this experiment tomorrow".

Paris' claim that Davy "appeared much surprised" slyly misrepresented the situation since, in Davy's brief addendum to Faraday's first paper on the liquefaction of the gases, Davy had pointed out (as had Faraday) that Faraday initially made the experiment at his suggestion. Davy also said he had anticipated liquefaction of the chlorine as one probable result. Faraday for his part said that he had "no doubt" that Davy had foreseen the result.

John Davy, a more reliable reporter than Paris about Sir Humphry, but also a man of exquisite sensitivity with respect to his brother's reputation, was triggered to rebuttal by what Paris had written. In his biography of Sir Humphry, John Davy declared (34):

... the account which Dr. Paris has given [of the condensation of the gases] in his work is partial, and, as it appears to me, incorrect and unjust, and not borne out by the published statements either of Mr. Faraday or my brother ... Dr. Paris's narrative imparts to the reader the impression, that Mr. Faraday was very unjustly treated; that Sir Humphry Davy took advantage of his situation, and endeavoured to appropriate to himself part of the merit of a discovery to which he was in nowise entitled ... I am surprised that Mr. Faraday has not come forward to do him justice.

This complaint galvanized Faraday to reflect again, now with the perspective gained by the passage of time and the death of Sir Humphry, on all of the events surrounding his election to Fellowship. As a result he added some details to the written record about his relationship with Davy. The response

which he prepared for John Davy paralleled in a way his earlier response to Warburton's charge. He first established a two-part "diary", the initial section of which he titled "Electro-Magnetism", the second, "Condensation of Gases". Eventually he inserted both parts into his copy of Paris' biography. The second part read as follows (35):

Condensation of gases

Before my account of the Hydrate could be printed, the other expts were made & Davys note to the R.S. read

Davy was Honorary Profr. until May 1824

Mar 1823 My paper on compd. hydrate chl. Quar Jour xv 71
April 1823

13 Mar 1823 Mine on fluid chlorine read 13 Mar 1823 Phil
Trans 1823 p 160 Mr. Brande secy R.S.

19 Mar 1823 Davys note to my paper read 19 Mar 1823 Phil
Trans 1823 p 164

Mar 1823 Mr. Brandes note to my paper Quar Journ xv 74.
April 1823

10 Apr 1823 Mine on condensation of several gases read 10
April 1823 - Phil Trans 1823 p 189

17 Apr 1823 Davy on appl of conden gas as Mech Agnt. read 17
Apr 1823 Phil Trans 1823 p 199

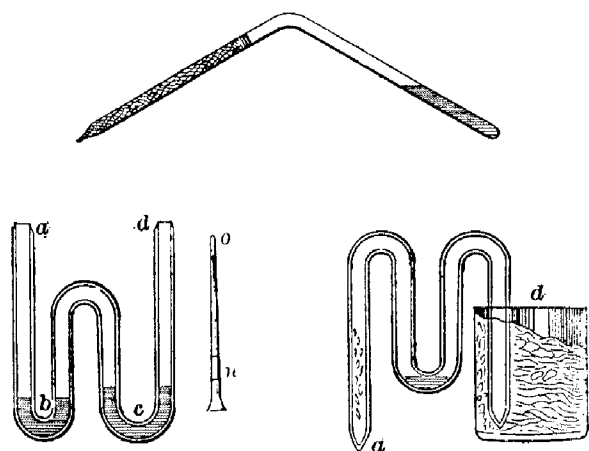
1 May 1823 Davy on change of vol by heat - read 1 May 1823
Phil Tr. 1823 p 204

Decr. 1823 My Historical Statement Quar Jour xvi 229.
Jany 1824

8 Jany 1824 My Election as F.R.S. 8 Jany 1824 names to my
certificate

This list of events, a product of Faraday's passion for accuracy and of his habitually meticulous approach to a problem, showed how the discovery of the liquefaction of chlorine plunged both Davy and Faraday into feverish activity as they sought to liquefy other gases. Faraday's second paper, "On the Condensation of Several Gases into Liquids," read to the Royal Society on 10 April, was supplemented by Davy with "On the Application of Liquids Formed by the Condensation of Gases as Mechanical Agents," read on 17 April. Davy further presented to the Society on 1 May his "Appendix to the Preceding Paper. On the Changes of Volume Produced in Gases in Different States of Density by Heat" (36).

Faraday's memorandum seems to have been an outline for a formal account he meant to write. Unquestionably it provided part of the data for the long letter he wrote to Richard Phillips, subsequently published in *Philosophical Magazine* (37). Faraday here revealed that he understood the full force of Paris' remarks, for he was at pains to show that while Sir Humphry may have anticipated liquefaction, he had not so informed Faraday. Faraday suggested that "[p]erhaps he left me unac-



Apparatus used by Faraday in his experiments on the liquefaction of gases.

quainted with ... [the results anticipated] to try my ability," conceivably because Davy had adopted such a strategy with him from time to time. Faraday wrote (38):

I have no doubt that he had them [expectations that chlorine would be liquefied]; and though perhaps I regretted losing my subject, I was too much indebted to him for much previous kindness to think of saying that that was mine which he said was his. But *observe* (for my sake), that Sir H. Davy nowhere stated that he told me what he expected, or contradicts the passages in the first paper of mine which describe the course of my thought, and in which I claim the development of the actual results. All this activity in the condensing of gases was simultaneous with the electro-magnetic affair; and I had learned to be cautious upon points of right and priority (38).

Frank and revealing as his letter was, Faraday had not acknowledged the existence and grace of Davy's compliment. Davy wrote that his conjecture had "been proved by experiments made [by Faraday] with ... much industry and ingenuity, and which I have had the pleasure of communicating to the Society" (39). Davy's tribute was both deserved and deliberate - Faraday's experiments displayed to splendid advantage his inventiveness and his extraordinary ability in chemical manipulation. In addition, by assisting his colleague toward Fellowship in the Royal Society, Davy also subtly enhanced the reputation of the Royal Institution, an action which would hardly go unnoticed. As President of the Royal Society, he could neither initiate nor sign Faraday's certificate, but he could aid his protégé's cause by providing, shortly before the election, a deft testimonial to Faraday's scientific ability.

Davy's addenda did more than establish priority and praise Faraday's ability. His brief notices enlarged the conceptual base for the phenomena Faraday had observed. In 1823 Faraday had called Davy's note "important"; in 1836 he acknowledged Davy's contribution by admitting that he "had not reasoned so deeply as [Davy] appears to have done", a justifiable admission. Both of Faraday's liquefaction papers were conceptually meagre. By initiating a discussion to account for all of the observed liquefaction phenomena, Davy enriched Faraday's experiments, cementing them firmly within accepted scientific doctrine (40).

Nonetheless, taken together, the papers still were incomplete, lacking what since has been called "der Anstand der Frage". Faraday's "Historical Statement Respecting the Liquefaction of Gases", published just a few days before his election, took care of the omission (41). (The appearance of the "Historical Statement" showed that it, together with Faraday's two papers and Davy's three supplements, comprised the totality of their research findings. Their great haste to publish had led to the fragmentation.) His report stood as a tacit warning to himself, to Davy, and to all scientists - searching the literature for prior pertinent accounts is an integral part of the research process. Faraday found that the literature yielded

accounts of several attempts to liquefy gases. At least one of them, that by the poet and inventor, Thomas Northmore (1766-1851), in 1805 reported the successful liquefaction under compression of both chlorine (not, of course, called by that name) and of sulfur dioxide. Nor had Northmore placed the report of his discovery where few would see it - *Nicholson's Journal* published his results in two parts (42). Northmore's third paragraph proffered a small surprise (42):

I communicated [my idea that "the various affinities which take place among the gases under the common pressure of the atmosphere, would undergo considerable alteration by the influence of condensation"] ... to the late chemical operator in the Royal Institution, a gentleman eminently conversant in the science, and with whom I was then engaged in a series of experiments: he not only approved of my design, but seemed to think it not improbable that an extensive field might thus be opened to future discoveries.

Until some time in 1804 the title "chemical operator" at the Royal Institution belonged to John Sadler (43). Because Davy appeared to have been unaware of Northmore's experiments (he had several opportunities for recall, since he read Faraday's paper before it was presented to the Royal Society, he presented it, and he also corrected the proofs for *Phil. Trans.*) the conclusion is forced on us that Sadler had not mentioned the incident to him, and that either Davy had not read the papers in *Nicholson's Journal*, or, if he had, he had forgotten them. There is also the possibility that some sort of primitive recollection of Northmore's results lingered in Davy's mind without a direct association; perhaps that slight memory trace inspired Davy to think that chlorine could be liquefied. Still, Davy's own conceptual base easily could have led him to the same conclusion. In all fairness it must be recalled that Northmore, unlike Faraday, employed fairly elaborate apparatus and that he offered little in the way of explanation of what he had observed (44). The simplicity of Faraday's experimental approach, heating substances in closed, bent tubes, beautifully exploited Davy's and his conceptualization about the nature and behavior of gases and liquids. Northmore's more elaborate attempts similarly exploited a conceptualization, but it was one derived from an intellectual base of about 1800, somewhat different from that of Faraday and Davy in 1823.

The matter was, to all intent, closed in 1824, and Faraday won his F.R.S. However, in 1844 Faraday returned to the subject, presenting to the Society his observations "On the Liquefaction and Solidification of Bodies Generally Existing as Gases" (45). He admitted to a "constant desire on my mind to renew the investigation", occasioned by the publication of papers by M. Thilorier, coupled "with considerations arising out of the apparent simplicity and unity of the molecular constitution of all bodies when in the gaseous or vaporous state ..." Passage of 20 years had altered neither the tenor of Faraday's papers nor the brilliance of his experimentation, but

his conceptualizations had altered.

The events preceding Faraday's successful election must have been an anguished time for both Davy and Faraday. The months during which Faraday's certificate was posted saw difficulties arise between two decent men: both were ambitious, both were proud, both were honorable, and both were bound by codes of proper behavior. Those difficulties cast a shadow over the balloting process of 8 January 1824. Davy could not risk being present, should Warburton, or one of his friends, change his mind and speak against Faraday - and Warburton by his own admission had, on 19 May 1823, told several people of his objection to Faraday's election. Davy - the embodiment of caution - did not go to the Royal Society meeting that day.

Who cast the black ball? We may probably never know, but we know some of the people it cannot have been. We know it could not have been Davy, nor could it have been Wollaston, because both were absent for the voting. It could not have been Warburton, since he promised Faraday his support. We know also the names of 29 others who would not have black-balled Faraday, those who had signed his certificate. We can say that whoever it was may have been moved by Warburton's first denunciation (46).

Despite the happy outcome of the election, the events of the summer produced repercussions. Faraday, in a letter to Warburton on 29 August, in which he thanked him for his support, described his own feelings. "Two months ago", Faraday wrote (47):

I had made up my mind to be rejected by the Royal Society as a Fellow, notwithstanding the knowledge I had that many would do me justice: and, in the then state of my mind, rejection or reception would have been equally indifferent to me. Now that I have experienced so fully the kindness and liberality of Dr. Wollaston, which has been constant throughout the whole of this affair, and that I find an expression of good-will strong and general towards me, I am delighted by the hope I have of being honoured by Fellowship with the Society ...

Faraday got his wish; no one could deny his scientific credentials. But what of Davy? In 1836 Faraday recalled (48):

I was by no means in the same relation as to scientific communication with Sir Humphry Davy after I became a fellow of the Royal Society as before that period ...

Faraday thought Davy now behaved guardedly in his presence, if not downright cautiously. When Faraday said he had "paid for" his Fellowship, he meant he had written a public apology to Wollaston, he had mollified a crusty Warburton, and he had lost Davy's closest scientific confidences. Still, outwardly things remained the same. Not only did Davy see and revise Faraday's manuscripts, but they went to the Royal Society

"through his hands", and Davy saw and revised the printer's proofs for *Phil. Trans.*. Faraday saw these acts as a "great kindness", saving him from committing "various grammatical mistakes", as well as removing "awkward expressions ... which might also have remained." Yet, although Faraday and Davy continued as colleagues, to Faraday it seemed as if they had become colleagues on a different level.

Davy's actions were predictable and complexly motivated. He did not want to create the impression that Royal Institution men had taken over the scientific community. Faraday's memorandum of events showed that Davy's resignation as Honorary Professor at the Royal Institution in May of 1824 was part of the sequence played out over Warburton's charges. While Davy continued as President of the Royal Society (Brande was Secretary) he was also working for the government on naval ship corrosion, a project he could not share with Faraday. It meant adopting a new level of behavior - Davy could no longer afford to be Faraday's scientific intimate.

Although one would be hard-pressed to think of a candidate more deserving of Fellowship in the Royal Society, or of one less likely to have advanced his reputation at another's expense, Faraday's candidacy became entwined with the desire for reform inflaming some of the Fellows. The events offer an abrupt and unanticipated glimpse into the complex politics operating within the Society. Whatever else might be said of it, the Royal Society was not a placid, untroubled body solely preoccupied with the generation and contemplation of scientific knowledge. After the death of Sir Joseph Banks, reform became a continual irritant. Reform meant more than redressing grievances of mathematicians and astronomers; it also meant recognition, within the Society and without, voiced or unvoiced, that the Society existed primarily to honor those whose main occupation was science; and that being a "scientist" (the word was not coined until 1841) meant pursuing a "profession". Faraday belonged on the rolls of the Society because he was an accomplished and brilliant professional.

When Davy wrote across Shuckburgh's certificate that it was unacceptable "there being no qualifications mentioned", he wished to establish a fundamental tenet of professionalization. One measure of "qualification" - publication - especially publication in the pages of *Philosophical Transactions*, paralleled a measure used by the older, established professions. They committed their members to the public performance of certain rituals: administering the sacraments, for example, or meting justice. That public performance, however, could not occur until an aspiring professional had undergone certain rites of passage and had met established standards for performance. For the practicing scientist, rites of passage were not clear cut. In 1821 British law had spoken directly to the issue, deeming that chemists were not to be regarded as "professionals", but were to be regarded as mechanics (49). The distinction arose because it did not seem to the judges that chemists were privy to a body of peculiar knowledge: some of them (Faraday had

been a prominent witness in the widely-reported case) obviously had not attended a university; some spoke with "barbarous" accents; some maintained suspect political affiliations; some espoused unconventional religious beliefs. Above all, scientific knowledge appeared to accrue to anyone who took the trouble to acquire it, frequently without guidance from established "professionals". Yet, the Royal Society, by asking that proposed Fellows exhibit certain "qualifications", had, in a way, asked for the public performance of a ritual - publication of scientific work previously reviewed by "professional" peers. Such a requirement introduced a unique condition into the requirements for a "professional" scientist. Unlike the clergyman, for example, whose license to baptize, once granted, endured, the professional natural philosopher or scientist had, in effect, to continue to renew his license by asserting his proficiency anew with each publication. Faraday could not be faulted on such a score, for he had several times offered up his "qualifications" for public scrutiny.

The professions, moreover, commonly claimed adherence to a set of ethical or moral guidelines. When Warburton set out to challenge Faraday's candidacy, he raised questions about Faraday's honesty. Clearly Warburton, viewing the community of illustrious men of science from the periphery, saw it as one whose members cleaved to a code of ethical behavior. That he eventually publicly absolved Faraday indicated that he thought Faraday had operated within acceptable boundaries - although Warburton, a hard man to shake from an opinion, declared that he was only marginally pleased with Faraday's explanation and apologies. Faraday's difficulties around his election dissolved when he showed that he had, indeed, behaved professionally and adhered to the established code of behavior. Before the election 29 members were convinced (if any of them ever had doubts); many more expressed their conviction by voting for him on 8 January 1824.

The circumstances surrounding Faraday's election to the Royal Society reveal an emerging consensus within its membership. Scientific achievement was becoming a sufficient criterion for election. In a few more decades it would become the only criterion. The aristocratic Fellows lost interest in science as it became increasingly specialized and less comprehensible to the dilettante. The power of the President passed to the Council, which achieved a majority of scientific members within a few years of Faraday's election. The Royal Society was on the verge, after a century and a half of existence, of becoming a "scientific" society, and Fellowship in it was to be reserved for scientific professionals.

References and Notes

1. This account of the election procedure is based on the *Journal Book of the Royal Society*, Vol. XLIII, 1819-1823 and Vol. XLIV, 1823-1827; on A. B. Granville, *The Royal Society in the XIXth Century*, Longmans et al, London, 1836, *passim*; and on J. Davy's *Memoirs of the Life of Sir Humphry Davy*, 2 Vols, London, 1836, Vol. 2, pp. 126-138.
2. H. Bence Jones, *The Life and Letters of Faraday*, 2 Vols, 2nd ed., Longmans, London, 1870, Vol. 2, p. 97.
3. Others refer to the social context surrounding Faraday's election as a "web of conflicting loyalties and commitments". See D. Gooding and F. A. J. L. James, *Faraday Rediscovered*, Macmillan, London, 1985, p. 7.
4. D. P. Miller, *The Royal Society of London 1800-1835: A Study in the Cultural Politics of Scientific Organization*, Ph.D. thesis, University of Pennsylvania, 1981; also "Between Hostile Camps: Sir Humphry Davy's Presidency of the Royal Society of London 1820-1827", *Brit. J. Hist. Sci.*, 1983, 16, 1-47.
5. H. Lyons, *The Royal Society, 1600-1940*, Cambridge University Press, Cambridge, 1944, p. 341.
6. *Ibid.*, pp. 341-342. We have accepted for the purposes of our argument the numbers reported by Lyons, even though his compilation has anachronistic weaknesses. For the period 1740-1860, he counted as "scientists" all Fellows categorized as mathematicians, astronomers, chemists, physicists, engineers, surveyors and hydrographers, instrument-makers and opticians, physicians and surgeons, botanists, geologists, zoologists and naturalists. Although one may quarrel with some of his assignments, there can be little doubt that his numbers reveal that the "makers" of science were a significant minority in the Royal Society until at least the mid-19th century.
7. A. B. Granville, *Science Without a Head*, Printed for the Author, London, 1830, p. 51.
8. Reference 5, p. 342.
9. For an analysis of the controversy surrounding Davy's election to the Presidency in 1820, with specific reference to the actions of the scientific "reformers" see L. F. Gilbert, "The Election to the Presidency of the Royal Society in 1820," *Notes Rec. Roy. Soc.*, 1955, 11, 256-279.
10. Reference 7, p. 97.
11. Herschel to Babbage, 26 April 1822, John Herschel papers, Royal Society of London library. Both Herschel and Babbage were active in the movement among the scientific Fellows to reform the Society. The "Hamilton" referred to was probably Rev. H. P. Hamilton, elected FRS in 1828.
12. Fellowship certificate of Sir Francis Shuckburgh, Royal Society archives. Quoted in J. Z. Fullmer, "Humphry Davy, Reformer," in S. Fagen, ed., *Science and the Sons of Genius: Studies on Humphry Davy*, Science Reviews, London, 1980, p. 84. Despite Davy's disapproval, Shuckburgh was successfully elected on 11 March 1824, two months after Faraday's election.
13. *Royal Society Catalogue of Scientific Papers (1800-1863)*, The Royal Society, London, 1867. Jeffreys, a more reliable source, listed a total of about 70 publications; see A. E. Jeffreys, *Michael Faraday: A List of his Lectures and Published Writings*, Chapman and Hall, London, 1960.
14. Quoted in reference 2, Vol. 1, p. 334.
15. Reference 7, p. 244.
16. C. Babbage, *Reflections on the Decline of Science in Eng-*

land, Printed for the Author, London, 1830, p. 51.

17. The 29 signatures on the certificate were as follows: William Hyde Wollaston, John George Children, William Babington, John Frederick William Herschel, John Lewis Guillemard, Richard Phillips, Charles Babbage, Grant David Yeats, Thomas Colby, William Prout, William Daniel Conybeare, Henry Thomas De La Beche, Daniel Moore, John Bostock, Peter Mark Roget, Augustus Bozzi Granville, Jonathan Frederick Pollock, Richard Horsman Solly, George Pearson, Henry Earle, Gilbert Blane, James South, Davies Gilbert, Robert Bingley, Alexander Crichton, John Ayrton Paris, John Frederick Daniell, Charles Hatchett, James Stodart. The identity of each proposer is given in the biographical register (or in note 1 accompanying letter 195) in F. A. J. L. James, ed., *The Correspondence of Michael Faraday*, Vol. 1, Institute of Electrical Engineers, 1991.

18. Phillips to Faraday, 3 May 1823, James, reference 17, letter 195, p. 315.

19. Faraday to Phillips, 5 May 1823, *ibid.*, letter 196, p. 316.

20. W. H. Wollaston, P. R. S., Copley Award Speech, 30 November 1820, *Royal Society Journal Book*.

21. Reference 2, Vol. 1, p. 310.

22. M. Faraday, "On Some New Electro-Magnetical Motions, and on the Theory of Magnetism", *Quart. J. Sci.*, 1822, 12, 416-421.

23. See L. Pearce Williams, *Michael Faraday*, Simon and Schuster, New York, 1971, pp. 137-190 for an extensive discussion of these events. Also useful for its liberal use of primary sources is reference 2, Vol. 1, p. 299-314.

24. W. H. Wollaston to M. Faraday, 1 November 1821. Quoted in reference 2, Vol. 1, p. 305. Williams (reference 23) saw this as a "chillingly cold" reply; more likely it was only representative of Wollaston's normally terse, often laconic, writing style.

25. H. Warburton to M. Faraday, 8 July 1823. *ibid.*, p. 311-312. Warburton referred to Faraday's paper "Historical Statement Respecting Electro-magnetic Rotation," published in July 1823 in the *Quarterly J. Sci.*, 1823, 15, 288-292. The manuscript of the paper in the Faraday Collection at the Royal Institution bears the following note in Faraday's hand: "this shown to Wollaston before being printed who made some pencil alterations and declared it to be 'perfectly satisfactory'". So corrected, the transcript was bound with Faraday's copy of his papers from *Phil. Trans.* Henry Warburton was a timber merchant, philosophical radical and Whig politician whose close friendship with Wollaston grew out of their mutual interest in geology. Warburton had been Wollaston's chosen biographer; his work never appeared.

26. M. Faraday to H. Warburton, 3 May 1823. *ibid.*, p. 308-309.

27. Reference 2, pp. 339-340.

28. *Ibid.*

29. *Ibid.*, p. 311.

30. J. F. W. Herschel Ms. Quoted in reference 9, p. 259.

31. Davy to Faraday, 29 June 1823, 23 July 1823 and 28 July 1823, letters all in the collection of the Institution of Electrical Engineers, London.

32. J. A. Paris, *Life of Sir Humphry Davy*, 2 Vols, Colburn and Bentley, London, 1830. Paris embroidered and enlarged anecdotes in

much of what he wrote; see J. Z. Fullmer, "Davy's Biographers: Notes on Scientific Biography," *Science*, 1966, 155, 285-291.

33. *Ibid.*, Vol. 2, p. 210.

34. Davy, reference 1, Vol. 2, p. 164. John Davy's grievance was indeed proper, but in directing it at Faraday he had missed his true target. It is also unlikely that the younger Davy was "jealous" of Faraday. The quoted passage sounded a note of wounded astonishment that Faraday had not felt impelled to defend Sir Humphry, as a dutiful younger "brother" might be expected to do. Dr. Davy and Faraday were bound by several ties: not only had they been roughly coeval at the Royal Institution, they appear to have been treated intellectually in about the same fashion by Sir Humphry.

35. Mrs. I. M. McCabe, Librarian of the Royal Institution, graciously provided the copy.

36. M. Faraday, "On the Condensation of Several Gases into Liquids", *Phil. Trans.*, 1823, 113, 189-198; H. Davy, "On the Application of Liquids Formed by the Condensation of Gases as Mechanical Agents", *Phil. Trans.*, 1823, 113, 199-203 and "Appendix to the Preceding Paper. On the Changes in Volume Produced in Gases in Different States of Density by Heat", *Ibid.*, 204-205.

37. M. Faraday, "On the History of the Condensation of the Gases, in Reply to Dr. Davy, Introduced by Some Remarks on that of Electro-magnetic Rotation," *Phil. Mag.*, 1836, 8, 521-529.

38. Reference 2, Vol. 1, p. 338.

39. H. Davy, "On the Application of Liquids Formed by the Condensation of Gases as Mechanical Agents," *Phil. Trans.*, 1823, 113, 199-203, p. 199.

40. These remarks are not meant to imply that Faraday's "ideas" were meager. His introduction of the "bent" sealed tube for heating the chlorine hydrate simultaneously exhibited conceptual understanding coupled with beautiful operational simplicity. What was "meager" was Faraday's discussion of the phenomena he exploited and described.

41. M. Faraday, "Historical Statement Respecting the Liquefaction of Gases," *Quart. J. Sci.*, 1823, 16, 229-240; published January 1824.

42. T. Northmore, "Experiments on the Remarkable Effects Which Take Place in the Gases, by Change in their Habitudes, or Elective Attractions, When Mechanically Compressed," *Jour. Nat. Phil. Sci. Arts.*, 1805, 12, 369-373; "Experiments on Condensed Gases," *ibid.*, 1806, 13, 233-236.

43. See J. Sadler, *An Explanation of Terms Used in Chemistry*, London: Royal Institution (1804) 22 pp. Sadler was designated "Chemical Operator to the Royal Institution" on the title page; W. G. Farrant held the same job from 1804-1806. Since in 1805 Farrant could not have been referred to as "late," in all likelihood Northmore experimented and discussed the liquefaction problem with Sadler.

44. A brass condensing pump, 3.5 to 5 in³ pear-shaped glass receivers a quarter inch thick, and a siphon gauge. Northmore also reported he wore wooden guards on his legs to prevent possible injury from shattered glass; his full report makes the reader rejoice that he was thus protected.

45. M. Faraday, "On the Liquefaction and Solidification of

Bodies Generally Existing as Gases," *Phil. Trans.*, 1845, 135, 155-177.

46. It is not possible to list all those who did attend the meeting and participated in the vote, as an attendance register was not kept. There is a record of Fellows who signed in guests, however, and from the appropriate entry in the *Journal Book of the Royal Society* for 1824, we know the following Fellows were in attendance: William Wilkins, James South (*), Alexander Crichton (*), John Knowles, Thomas Young, Thomas Tooke, Graves Haughton, Richard Phillips (*), Edward Troughton, Grant David Yeats (*), Edward Sabine, John Frederick Daniell (*), Temple Chevallier. There is also a record of those who were present for the meal of the Royal Society dining club that followed the meeting. It is likely (but not certain) that they also voted in Faraday's election: Dr. William G. Maton, Wilbraham, T. Murdock, J. F. W. Herschel (*), W. Wilkins (*), W. Marsden, A. Johnston, Lambert, Raper, Branene (probably Brande). The names marked with (*) had signed Faraday's certificate.

The authors thank Dr. Frank James of the Royal Institution for providing the lists of names.

47. Faraday to Warburton, 29 August 1823. Quoted in reference 2, Vol. 1, p. 313.

48. *Ibid.*, p. 340.

49. J. Z. Fullmer, "Technology, Chemistry and the Law in Early 19th Century England," *Technology and Culture*, 1980, 21, 1-29.

June Z. Fullmer is Professor of History at Ohio State University, Columbus, OH 43210 and is author of "Sir Humphry Davy's Published Works". Melvyn C. Usselman is Associate Professor of Chemistry at the University of Western Ontario, London, N6A 5B7, Ontario, Canada and is interested in the modern replication of classic experiments in the history of chemistry. He is currently working on a biography of William Hyde Wollaston.

EDUCATING THE JUDGMENT: FARADAY AS A LECTURER

Geoffrey Cantor, University of Leeds

Those who heard Faraday lecture unanimously declared that he was a superb teacher. Moreover, they claimed that attendance at his lectures - whether a Friday Evening Discourse, a series on a specific topic, or a set of Juvenile Lectures - was a memorable experience. While there was consensus on these matters, his auditors differed in their reactions to Faraday and his style of lecturing. This diversity is worth exploring and in the ensuing discussion I shall divide assessments into three categories, starting with references to the specific skills he deployed in the lecture theatre. The second group of comments refer to the personal qualities he projected and particularly to



A late 19th-century woodcut of Faraday with scenes from his life in the margins. Note that the bottom scene shows him lecturing. No other scientist has so often been depicted giving popular lectures. In addition to the three illustrations in this article and the view on the front cover, at least two additional period woodcuts of Faraday lecturing are known to exist.

his ability to relate to his audience. Thirdly, and most importantly for the purpose of this paper, will be his appeal to ideas and values that transcended the particular scientific topics he discussed.

Turning first to Faraday's lecturing skills we find that many of his auditors praised his eloquence and the clarity of his exposition. For example, one lay member of his audience noted that he was "Always clear in his statements and explanations" (1). Others, especially men of science, were particularly attracted to his judicious use of illustrative experiments. Thus the American electrician Joseph Henry was impressed by Faraday's "inimitable tact of experimenting" while William Crookes described Faraday's virtuosity as "a sparkling stream of eloquence and experimental illustration" (2). Likewise the Genevan scientist Auguste De la Rive commented on Faraday's ability to "combine animated and often eloquent lan-