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SCIENCE AS A SPIRITUAL PATH: MICHAEL FARADAY'S APPRENTICESHIP

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Michael Faraday's Apprenticeship

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Can science be a spiritual path?

This question links two seemingly incompatible activities and aspirations. Do these well-trodden paths lead in different, if not opposite directions? Science is active and manipulative (of thoughts as well as things); it analyzes, dissects, selects and simplifies, working with partial and incomplete models of the world. This means of acquiring natural knowledge sets it apart from the spiritual quest. On the other hand, science has intellectual, aesthetic, practical and religious dimensions, and it would be presumptuous to suppose that scientific activity has not had, or cannot have a spiritual dimension. Yet there has never been a great spiritual teacher who was also a scientist. The provenance and purpose of scientific knowledge is change in the external world. Insofar as spiritual teachings seek change, they do so through change in the consciousness of individuals. Does the image of diverging paths reflect our preconceptions about science and spirituality rather than some essential, irreconcilable difference between them?

The suggestion that scientific persuits are compatible with spiritual aspirations (or even conductive to them) arises because of the lives of a very few scientists. I suspect that an answer to our question has more to do with a quality such people achieved than with the nature or purpose of their activity. This quality is the extent to which they were able to

transcend the ego. Einstein saw science as one means of liberation from the temporal self. Faraday conducted his science according to a discipline of self-observation and what he called 'self-abnegation'. In this respect, I shall argue, his science was as much an expression of his spirituality as it was an expression of the intellectual and practical implications of his religious beliefs.

Could a scientist's writings show us that science was, in its own right, a spiritual path? I doubt that they could, for two reasons. The first is that it is so easy for us to read spirituality into a scientist's less worldly pronouncements, especially when -- as with Einstein -- he fits the image of the pure scientist as an unworldly inquirerer after truths that are not of the marketplace. This is not to devalue, say, Einstein's expressions of a 'cosmic religious feeling'.[1] But we need to consider whether such words reflect the aspirations of maturity rather than a state of being achieved much earlier and through science. The testimony of friends and colleagues is another source of evidence about a person's spirituality. Faraday insisted -- both in private correspondence and in public -- on a separation between matters religious and scientific. Yet the physicist John Tyndall still saw that

> contemplation of Nature, and his own relation to her, produced in Faraday a kind of spiritual exhaltation ... His religious feeling and his [science] could not be kept apart; there was an habitual overflow of the one into the other.[2]

Tyndall, whose materialist metaphysics were incompatible with Faraday's own beliefs, also perceived that the spiritual strength Faraday received on Sundays sustained him throughout the week. Tyndall's testimony suggests

that Faraday's scientific work benifited from the strength of his religious commitments.[3] Personal qualities cited by friends and colleagues may well indicate a transcendence of self and of worldly values, but this may have owed little or nothing to science. This sort of testimony shows at best that a scientific mode of knowing has coexisted with a spiritual one, not that Faraday's spirituality was somehow enabled by his life's work. We need to ask a further question: where science was a spiritual path, was this walk an expression of a spirituality achieved by other means?[4]

To approach these questions it is as important to convey a little of the quality of Faraday's scientific activity as it is to develop Faraday's articulate and public views on science and religion.[5] It seems to me that as far as spirituality is concerned, a person is not made special by the fact that he or she is a scientist: scientists' pronouncements about themselves should be read in the light of how they actually did their work, how they lived and how they affected people around them. In this paper I can convey only a little of the quality of Faraday's work.[6] Before doing so I want to explain my caveat about the interpretation of scientists' religious and spiritual utterances. This is needed because the western intellectual tradition defines knowledge as an intellectual (linguistic) category, separating knowledge from value and, more fundamentally, divorcing knowing from being. The focus on manipulable beliefs means that most of the considerable literature on the interaction of western science with religion and with theology tends to deal only with the intellectual dimension, that is, with systems of <u>beliefs</u>, which are construed in terms of the assent of individuals to certain propositions. Important and interesting though it is, this sort of history does not

address spiritual awareness as something which may inform attitudes, shape practices and inspire scientific activity.[7] Can the spirituality of a scientist be discussed on an intellectual plane? In considering whether science and spirituality are merely compatible or are sometimes one and the same path, we should be prepared for the possibility that the harmony of science and spirit cannot be captured fully in a web of words. Knowing and being may not be related in the ways that historical explanations require.

Faraday's life provides a contrast to the traditional approach to 'science and religion' as distinct but interacting systems of belief. As we'll see, certain of Faraday's religious beliefs -- acquired in childhood but renewed by his conversion to Sandemanianism in 1821 -- would make it seem less likely that he should have made so great a contribution to natural science. Sandemanianism was a demanding version of Christianity which required that he practise his faith in the smallest details of life as well as the greatest. That is to say, it emphasised the implementation of Christ's teachings in everyday life and conduct.[8] The Sandemanians or Glasites were a dissenting sect who believed that the truth of the Bible was to be recovered by as literal a reading as possible.[9] Having no clergy to guide and instruct them made the Bible all-important to the conduct of their lives and their worship. I believe that Sandemanian views on the fallibility of theology encouraged Faraday to adopt an experimental path in science. They coloured his attitude to theorizing in science, reinforcing his distrust of theoretical (and, especially, mathematical) interpretations of nature.[10] As a Sandemanian Faraday would not have accepted that the ~~the~~ book of nature is written in a language so removed from experience as is the language of mathematics.[11] His often playful

enjoyment of the imaginings of the mind -- fiction, poetry, science and (presumably) theology -- was bounded by a deep awareness of the aspirations of theories and theologies to comprehend the world through intellectual ordering.[12] Theories were to be admired and used but they were more 'tinged with humanity' than with the divine, for our humanity enters alike into the construction of natural theology and mathematical natural philosophy. Both may come between the observer and the Book of Nature. Because their humanity engenders a power to promote and preserve illusion -- or as he called it -- 'error', theologies no less than philosophies should be held 'at arms length'. Their humanity makes all people -- including scientists -- 'active promotors of error'. Notheless, Faraday believed, it is possible to learn something of God's creation. He devoted much of his energy towards doing just that, with results that have won him a place amongst the very best experimentalists of western science. In the process Faraday came to realize that science requires a form of knowledge traditionally excluded by the methodologies of scientists, namely, self-knowledge. I will examine his arguments about the relationship between self-knowledge and public forms of knowledge (such as science) in a later section.

A brief life

Faraday's ambivalent attitude to intellect makes him an unusual companion for the greatest of western scientists. A brief look at his life may help us to understand this peculiarity. Faraday was born in September of 1791, the third son of James Faraday, a blacksmith living in Stoke Newington, then on the outskirts of London.[13] Faraday was raised in circumstances that hardly foretold a life in science. He had a little

public education until he was 13, and of course none at all in any of the sciences. Becoming apprenticed to a bookbinder in 1805 gave him access to works such as the Encyclopaedia Britannica and he was able occasionally to attend courses of lectures given, for example by Jack Tatum and by Humphry Davy. This self-education convinced Faraday that he wanted to become a chemical philosopher. By 1813 he had become a journeyman printer but was released from this when Sir Humphry Davy was persuaded to employ Faraday as his assistant. Though Faraday's position was at first a lowly one, it placed him in a leading laboratory with Davy and W. T. Brande, two very able and experienced experimentalists. His tour of Europe from 1813 to 1815 as Davy's amanuensis was an excellent introduction to the leading edge of continental science. Faraday learned quickly and was soon contributing to the analytical work of the Royal Institution's laboratory. By 1821 he had begun to eclipse his teacher and mentor, with the discovery of electromagnetic rotations in 1821, soon followed by the discovery of hydrocarbons (including benzene) in 1825 and work on stainless steels and optical glass, commissioned by the Royal Society.[14] Faraday became 'Assistant and Superintendent' of the laboratory in 1815 (when he was given lodgings within the instituion), 'Superintendent' of the house of the Royal Institution in 1821, and Director of the Laboratory in 1825. He lived at the Royal Institution his wife Sarah until he retiremed to Hampton Court in 1862. He carried a considerable responsibility for the running of the Royal Institution, which housed Britain's foremost working laboratory. The great lecture theatre was the focal point of metropolitan science for much of the nineteenth century.[15]

Much of his time in 1820's and the early 1830's was devoted to applied

science, particularly consulting work ('professional business', as he called it).[16] The time available for research was limited, but enormously productive. Following on from the discovery of electromagnetic induction in 1831, Faraday investigated and enunciated two laws of electrochemistry in 1833-4 (his electrochemical nomenclature is still in use) and self-induction in 1834. A thorough experimental investigation of electrostatic phenomena lead to the invention of the Faraday cage, an experimental proof that inductive capacitance is specific, a direct challenge to the established distinction between conductors and insulators and to the extension of his model of lines of induction to electrostatics.[17] The magnetic analogue to electric capacity eluded his experiments until 1845, when he showed that light is affected by magnetism. This, the magneto-optic effect (or Faraday-effect) led directly to his demonstration, between 1845 and 1848, of the magnetic susceptibility all matter. By 1848 he had included crystalline forces and proven the magnetic susceptibility of gases.[18] He had nearly completed a comprehensive, unified theory of electricity and magnetism that promised to incorporate optical phenomena as well. During the 1850s Faraday was largely concerned to develop and defend this theory of lines of electric and magnetic force.

'Mental Education'

I remarked earlier that, although he believed that their humanity makes scientists 'active promotors of error', Faraday thought that natural philosophers could learn something of God's creation. This requires a form of knowledge -- self knowledge -- that is excluded by the scientific method, which is meant to winnow out the objective, natural phenomon from the personal, or 'observer-effects'. Faraday introduced this point in a

lecture that he gave in May of 1854.[19] At first sight this lecture has little to say about a spiritual dimension to science or anything else, for his declared purpose is to remedy the credulity and gullibility of a public willing to misuse scientific opinion in support of unsubstantiated and even physically impossible claims. Faraday had himself been misused in connection with a controversy about the creation of living organisms with electric currents in 1836. Then, some had claimed that he endorsed experiments by Andrew Crosse which created living mites from inert matter by electrical means.[20] During a later craze for spiritualism and table-turning, others had invoked Faraday's name in similar ways. By mid-century Faraday was one of Britain's best-known scientists and, when he chose to be, a very public figure. As the greatest experimentalist of his day he was expected to apply scientific method to determine whether material objects had indeed been moved by natural or by supernatural influences.

Faraday responded at first in the way you might expect an established expert to respond. He asserted the authority of established scientific laws and experimental practices against the claims of the para-normal.[21] He also drew another boundary, asserting the independence of religious and spiritual certainties from the "exertion of [our] mental powers". This is one source of the mistaken view that Faraday kept his science and religion apart.[22] Much of the lecture dealt with conventional problems of observation and errors of perceptual judgement resulting from lack of education and training -- and he offered equally conventional remedies ('mental' discipline). Although to disprove spiritualism was the overt agenda, it was not his main concern. For those who could hear it, this lecture carried a more radical message. In tracing the problem to the poor

'mental condition' of man, Faraday challenged the accepted view of scientific knowledge itself. This in turn placed a very different interpretation on his opening remarks about the separation of his science from his religion.

Faraday set his discussion of mental education in the context of a 'distinction .. of the utmost importance':

> High as man is placed above the creatures around him, there is a higher and far more exalted position within his view; and the ways are infinite in which he occupies his thoughts about the fears, or hopes, or expectations of a future life. I believe that the truth of that future cannot be brought to his knowledge by any exertion of his mental powers ... that is it made known to him by other teaching than his own, and is received through simple belief of the testimony given.[23]

Here he introduced an 'absolute distinction' between religious and ordinary belief:

> ...let no one suppose for a moment that the self-education I am about to commend in respect of the things of this life, extends to any considerations of the hope set before us, as if by man reasoning could find out God.[24]

Thus, in a well-known passage, he says he is "content to bear the reproach" that he is being weak in "refusing to apply those mental operations which I think good in respect of high things to the very highest." This refusal reflects his understanding of the sort of motivations that affect and limit the application of ordinary "mental operations" to matters of faith and the spirit. In other words, this passage is about the state of enlightenment

(or level of being) of those who would reason from Nature to God, not about our powers of reasoning.[25] He goes on to say, paraphrasing Romans 1, v.20, that

> even in earthly matters, I believe that the invisible things of Him from the creation of the world are clearly seen, being understood by the things that are made, even His eternal power and Godhead ...[26]

Why does he claim to be using only the 'ordinary faculties of the mind in ordinary things'? This looks like a conventional expression of humility. It probably was intended to discourage his audience from drawing theological conclusions from science. I think that Faraday was also preparing his audience for a less palatable, more radical message.

Elspeth Crawford has drawn attention to one aspect of this: that is Faraday's claim for a need for self-awareness with regard to the disturbing influence of emotions.[27] Objectivity in science requires that the observer be just as aware of his emotions and desires and their effect on what he is doing, as he is of external experience. Internal observation is essential to observation of the external world, unless we are to be satisfied with mere projections of our own hopes and fears. This remedy for the misunderstanding and misuse of scientific knowledge goes far beyond the issues of credulity versus authority, or the policing of boundaries between science, pseudo-science and religion. It is very different from the usual notion of scientific objectivity, to be achieved through the elimination of subjective aspects of experience. Moreover, it is unusual for a scientist to make this sort of claim in public, especially from an established <u>scientific</u> platform. This lecture was given in the famous

lecture theatre of the Royal Institution in the presence of Prince Albert. It would have been easy for Faraday to use this august occasion to present science in terms more acceptable to his public, say, as a moral and intellectual discipline, and to promote its importance to general education. He chose instead to attack --albeit obliquely-- a false view of knowledge implicit in the conventional methodology of science.

Since the seventeenth century the methodologies of scientists and philosophers of science use nature (tried in experiment) as an objective means of discriminating between the natural (taken to be external) and the merely personal (internal), in order to eliminate the latter.[28] Faraday knew that there is a created, natural order, but he did not believe that nature can be observed in the way that empiricists assume. Lack of self-knowledge is an obstacle to having knowledge of _any_ kind. Thus,

> Among those points of self-education which take up the form of _mental discipline_, there is one of great importance, and, moreover, difficult to deal with, because it involves an internal conflict, and equally touches _our vanity and our ease_.[29]

The conflict consists in our "tendency to deceive ourselves regarding all we wish for, and the necessity of resistance to these desires". Faraday had given over thirty years of his life to the attempt to read the book of Nature. The Sandemanianism in his Christianity promised that, like the Bible, this book could be open to anyone who sought to read it _without prejudice_. Is prejudice merely personal bias, which can be removed by the adherence to scientific method? In practice the scientific method commits scientists to a degree of intellectual honesty, to submit to the critical

appraisal of their colleagues, and so on. One of the fundamental differences between scientific methods and a spiritual ones is that the former seek to remove the personal aspects of experience while the latter depend upon self-observation to transcend the ego. What Faraday has in mind resembles scientific method less than it does a spiritual discipline. Referring to his own experience, he explains that

> it is impossible for anyone who has not been constrained, by the course of his occupation and thoughts, to a habit of continual self-correction, to be aware of the amount of error in relation to judgement arising from this tendency [to deceive ourselves].[30]

As I show elsewhere,[31] Faraday's letters and his laboratory Diary support his testimony that he had found, time and again, that

> The force of the temptation which urges us to seek for such evidence and appearances as are in favour of our desires, and to disregard those which oppose them, is wonderfully great.[32]

By our nature "we are all, more or less, active promoters of error" because we fail to practice "wholesome self-abnegation".[33] Self-education "consists in teaching the mind to resist its desires and inclinations ..." This is "the most important of all, not only in things of natural philosophy, but in every department of daily life."[34]

This last phrase removes the distinction between science and other aspects of life that had Faraday erected at the beginning of his lecture. Faraday knew that human fallibility is not confined to non-scientific matters. Similarly, failures of judgement in scientific matters reflect,

and will be carried "into other matters of life" because "proof of deficient judgement in one department shows the habit of mind, and the general want, in relation to others".[35] This is why Faraday had insisted in a letter of 1844 that "there is no philosophy [i.e., science] in my religion" and why he insisted on this occasion that man cannot find our God's nature by reasoning. Obviously we cannot infer from this sort of statement that there was no religion in his science.

The first remedy he proposes for failures of judgement is 'nature's school': "all persons may find in natural things an admirable school for self-instruction".[36] This could be read as an appeal to contemporary expectations that science, the study of God's created order, could provide for moral uplift and self-improvement. However, Faraday's own experience showed that such instruction would be worthless without the second remedy: disciplined self-observation. This comes to terms with the very humanity of the would-be student of nature. Although the overt message of this lecture is a moral one, 'mental education' is more than a moral or psychological discipline. It is needed in every area of life, science, too, must involve an attempt to purify one's perception of the influence of ego.[37] Insofar as he was able to practise it according to the spiritual disciplines of Sandemanian Christianity, Faraday's science challenges the traditional separation of personal experience from objective knowledge.

'Tinged with Humanity"

This lecture shows that towards the end of his career Faraday had come to practice science by trying to free himself of prejudice by freeing himself of its sources, so that a little of God's truth might be revealed. It was not a means of producing knowledge according to certain

prescriptions and conventions. There can be little doubt that Faraday sometimes achieved a state of openness to unresolved experience, setting aside the demand of intellect for order and meaning, so as to accept a play of experiential possibilities. Some of his most original work involved rendering these experiential possibilities, and this required that he avoid premature judgements about just how they should look or what they might mean.[38] Many scientists are capable of this 'creative uncertainty', but Faraday seems to have had an unusual ability to stay with something even if it made no sense or was upsetting to his 'favourite notions'. The ability to suspend judgment may be likened to what the poet John Keats (rather unpoetically) called 'negative capability', a state of "being in uncertainties, mysteries, doubts, without any irritable reaching after fact and reason".[39] Occasionall his laboratory Diary shows Faraday trying to record his uncertainty about just how to see (resolve) some phenomenon, or setting out his mental preferences explicitly, so as to be reminded of their influence on perceptual judgements and on subsequent interpretation of resolved experience. After all, these notions expressed mere human aspirations for order.

When read in the context of his Sandemanian Christianity, Faraday's lecture on mental education helps us to understand why he did this. Had he always lived, worked and thought in this way? A letter of 1826 shows that he already believed that the most important limitation of the human condition is the partiality and fallibility of ordinary knowing:

> However strong and certain the appearances [of natural phenomena] are to me, if I venture an internal judgement, I am always wrong in something; and the only conclusion that I

> can come to is, that the end is as beneficial as the means of its attainment are beautiful. So it is in life ...[40]

The possibility of acting in, and upon the world depended upon his awareness and acceptance of his limited and fallible judgement:

> The point is this: in all kinds of knowledge I perceive that my views are insufficient, and my judgement imperfect. In experiments I come to conclusions which, if partly right, are sure to be in part wrong; if I correct by other experiments, I advance a step, my old error is in part diminished, but is always left with a tinge of humanity, evidenced by its imperfection.[41]

Christian teaching emphasises the finitude and imperfection of human endeavour. Faraday's acceptance of this was reinforced by his Sandemanianism, and he was a Sandemanian long before he became a scientist.

Nature's Apprentice

These passages show that the lecture on mental education, given when Faraday was 62, describe a way that Faraday had tried to follow since the 1820's, if not before. Besides a 'placidity' and readiness of mind, his faith assured Faraday that the value of his endeavours was not tied to the opinions of men; there was no need to triumph over the views of others. This is why, by contrast to many of his contemporaries, he was not concerned to establish views as his own, or to establish his views as scientific doctrine. Nor did he ensure the continuation of his work by building up a school of 'Faradayan' students, he made no attempt to win influential office and declined one of most presitigious -- the presidency

of the Royal Society -- when pressed to stand for it. As Pearce Williams points out -- "When one basks every week in the glow of eternity, years, decades even centuries seem trivial."[42]

This is shown in the quality of his daily working, as well as by his verbal and pictorial expression of that work. Isaac Newton once descrobed his life's work as having been playing with pebbles whilst the whole ocean of truth lay undiscovered before him. In Faraday's Diary a narrow and often very practical focus informs and interacts with a larger, intellectual and holistic vision in which each entity or phenomenon owes its existence, meaning and purpose to the whole. There is a painstaking attention to every aspect of a phenomenon and an attempt to follow where nature may lead. Here the human timescale seems unimportant: Faraday could spend months, for example, exploring the details of the behaviour of reagents near the surface of an electrode, just to establish whether secondary chemical actions would intefere with measurements he was making to establish laws of electrochemical action. How much he could discover was unimportant, provided that it was as free as possible of prejudice and error.

In his dealings with others, it is striking that Faraday avoided controversy and that his response to criticism was usually to clarify his position, always drawing attention to the dangers of reading more into the language of human experience than nature had shown. It is as though he regarded himself as a means of disclosing or conveying natural knowledge, which he thought scientists have a duty to do.[43] Of course Faraday invested enormous amounts of time and energy in the construction and defense of a unified field theory. This explained material properties such

as inertial mass -- traditionally treated as essential to (or inherent in) individual discrete bits of matter -- relationally, that is, as properties an entity may have in virtue being part of a larger whole, which Faraday called the "great field of nature".[44] Yet, even after forty years, Faraday was able to set aside this investment of himself just in case he had been mistaken. For example, in 1856, close to the end of his scientific career, he re-opened a line of enquiry about the relationship between aether and matter, taking up a research project that obliged him to re-evaluate views he had developed many years earlier.[45]

In this respect Faraday remained apprenticed to Nature: unaffected by public acclaim for his mastery of experimental skills, he never allowed himself to assume the status of a Master theorist. Faraday could do this because he had long ago discovered something of greater importance: a unity of activity and purpose that few people achieve in any walk of life. He practiced science in an enlightened way. Although science was not a spiritual path in its own right -- any more than spinning was for Ghandi -- it became an expression of Faraday's spirituality.

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ENDNOTES

1. Quoted in R. Ravindra, 'Science as a Spiritual Path', Journal of Religious Studies, 7, 1979, 78-85, p.80.

2. J. Tyndall, Faraday as a Discoverer, (London, 4th ed. 1868), p. 178.

3. See also H. Bence-Jones, The life and letters of Faraday, (2 vols., London, 1870) and G. N. Cantor, 'Reading the Book of Nature: the relation between Faraday's Religion and his Science', in D. Gooding and F. James, eds., Faraday Rediscovered, (London and New York: Macmillan/Stockton, 1985), pp. 69-81.

4. This seems likely, given the different sorts of knowledge acquired by the sciences and by spiritual disciplines. Moreover, all spiritual traditions emphasize the personal nature of spirituality whereas science seeks a collective, publically certified knowledge.

5. I develop this theme in a forthcoming biography of Faraday, Nature's Apprentice.

6. Tyndall attempted to do this (op. cit. note 2). See also T. Martin, ed., Faraday's Diary. Being the various philosophical Notes of experimental Investiation made by Michael Faraday ... 1820-1862, (7 vols. + index, London: Bell, 1932-36), and for studies of Faraday's experiments based on his diary, see: D. Gooding, 'Final steps to the field theory: Faraday's study of magnetic phenomena, 1845-50', Historical Studies in the Physical Sciences, 11, 231-75 and The Making of Meaning: agency, observation and the language of the early field theory, (Dordrecht and Boston: Kluwer/Nijhoff, in preparation), especially chapters 2 and 5.

7. See, e.g. R. Hooykas, Religion and the Rise of Modern Science, (Edinburgh: Scottish Academic Press, 1973).

8. Sandemanianism is named after Robert Sandeman, who married the daughter of one John Glas, a dissenting minister of the Scottish Presbytery who led a sect that had broken away from the established church in 1730. A similar sect, founded by Benjamin Ingham in Yorkshire ten years later, joined the Glasite communion in 1760. Robert Sandeman subsequently provided a unifying theology for the small but growing group. For the origins of the Sandemanian Church see: J. F. Riley, The Hammer and the Anvil: a background to Michael Faraday, (Clapham, Yorkshire, 1954), Bence-Jones (op. cit. note 2), and L. P. Williams, Michael Faraday. A Biography, (London: Chapman and Hall, 1965).

9. For John Glas' position on this, see Cantor, op. cit. note 3, p. 73 ff. The implication is that theology -- as a construction of human intellect -- comes between the individual and the word of God as revealed in the Bible. The Sandemanians dispensed with theologians and ministers in favour of an eldership for each church.

10. Soon after his discovery of electromagnetic induction Faraday explained to a friend that he would call his resarches 'experimental' to express their difference from the work of 'high mathematicians' who anticipate nature rather than observe it. See D. Gooding, 'A Convergence of Opinion on the Divergence of Lines: Faraday and Thomson's Discussion of Diamagnetism'. Notes and Records of the Royal Society of London, 36, 1982, 243-59, at pp. 246-8.

11. Faraday's preoccupation with plain, descriptive language was partly due to the influence of Lockean ideas which he absorbed through the

writings of Isaac Watts, particularly The Improvement of the Mind, (London, 1811). His assiduous application of their precepts owes a great deal to attitude shaped by Sandemanianism. On this see my forthcoming biography of Faraday, Nature's Apprentice, and Cantor (op. cit. note 3, p.70 ff.), who argues that the Sandemanians did not treat the Bible as a basis for developing a natural theology. The sect produced little in the way of theological or philosophical writings. Intellectual disputation may even have been discouraged.

12. Faraday's work was of course influenced by theoretical, metaphysical and epistemological precepts. The most general and fundamental are those of a Christian worldview, e.g., a teleological understanding of certain laws of motion and of the conservation of force. Their role is to create a general framework of possibilities (within which Faraday constructed explanations of natural phenomena) rather than a platform of axioms upon which a theory of nature is constructed. See D. Gooding, 'Metaphysics versus Measurement: the Conversion and Conservation of Force in Faraday's Physics', Annals of Science, 1980, 37: 1-29 and 'Empiricism in Practice: Teleology, Economy and Observation in Faraday's Physics', Isis, 1982, 73: 46-67.

13. See Tyndall, op.cit. note 3, Bence-Jones, op.cit. note 3, Williams, op.cit. note 8, and S. Forgan, 'Faraday -- from Servant to Savant: the Institutional Context', in Gooding and James, op.cit. note 3, pp. 51-67.

14. For Faraday's and Davy's changing relationship see D. M. Knight, 'Davy and Faraday: Fathers and Sons', in Gooding and James, eds., op.cit. note 3, 33-49.

15. The Friday Evening Discourses, which Faraday established in 1825,

continue to this day. Between 1825 and 1861 he gave over a hundred of these. For the importance of the Royal Institution, its laboratory and lecture theatre in the nineteenth century, see Williams, op. cit. note 8, M. Berman, Social Change and Scientific Organization: the Royal Institution, 1799-1844, (London: Heinemann, 1978), Forgan, op. cit. note 13, and essays in I. Inkster and J. Morrell, eds., Metropolis and Province: Science inBritish Culture 1780-1850, (London, Hutchinson, 1983).

16. Tyndall, op.cit. note 3, p. 181. Besides his superintendence of the house of the Royal Institution and his lectures and analytical work there, Faraday taught chemistry at the military academies at Woolwich and at Addiscombe.

17. See D. Gooding, 'Conceptual and Experimental Bases of Faraday's Denial of electrostatic Action at a distance", Studies in History and Philosophy of Science, 9, 1978, 117-49 and ' "In Nature's School": Faraday as an Experimentalist', in Gooding and James, eds., op. cit. note 3, 105-135.

18. See Gooding, 'Final Steps', op.cit. note 6.

19. 'Observations on Mental Education', reprinted in M. Faraday, Experimental Researches in Chemistry and Physics, (London, 1859), pp. 463-491.

20. See J. Secord, 'Extraordinary Experiment: Electricity and the Creation of Life in Victorian England', in D. Gooding, T. Pinch and S. Schaffer, (eds), The Uses of Experiment, (Cambridge: Cambridge University Press, 1988), pp. 337-383. Faraday alludes to this episode in op. cit. note 19, at p. 487.

21. Op. cit. note 19, p. 466-72.

22. Despite some good discussions (such as Williams, op. cit. note 8 and Cantor, op. cit. note 3) the idea persists that Faraday consciously kept religion and science apart (see J. Polkinghorne, One World: the interaction of science and theology, (London, SPCK, 1986), p. 97). Faraday did say in a letter to Maria Edgeworth, that "there is no [science] in my religion" and -- as we see below -- he distinguished religious knowledge from every other kind. Such comments need careful interpretation because, aside from them, nothing else in Faraday's life supports the view that he did keep the two apart. Like Tyndall (cited earlier), I am doubtful that he could have done in any case.

23. Op. cit. note 19, p. 464.

24. Ibid.

25. This is why he makes it clear that there is more than mere 'compatibility' between "those things of man which can be known by the spirit of man which is within him, and those high things concerning his future, which he cannot know by that spirit", ibid., p. 465.

26. Ibid.

27. In 'Learning from Experience', in Gooding and James, op. cit. note 3, pp. 211-227.

28. For the distinction between external and internal knowledge see R. Ravindra, 'Experiment and experience: a critique of modern scientific knowing', Dalhousie Review, 55, 1975/76, pp. 655-674.

29. Op. cit., p. 475.

30. Ibid.

31. In Nature's Apprentice.

32. Op. cit., p. 475.

33. Thus he remarks, "... I believe that a very large proportion of the errors we make in judgement is a simple and direct result of our perfectly unconscious state", ibid., p. 465. To Faraday it was self-evident that "no man can examine himself in the most common things, having any reference to him personally, or to any person, thought or matter related to him, without being soon made aware of the temptation and the difficulting of opposing it. I could give you many illustrations personal to myself, about atmospheric magnetism, lines of force ... &c.", ibid., p. 477.

34. Ibid., Faraday's emphasis.

35. Ibid.

36. Ibid., p. 473.

37. Notice that Faraday does not suggest that emotions should be eliminated or supressed -- only that their effects should be observed and understood. For Faraday's use of anger, see Tyndall, op. cit. note 3, pp. 43-44.

38. See D. Gooding, 'Thought in Action: Making sense of Uncertainty in the Laboratory', forthcoming in M. Shortland, ed., History of Science in the School Science Curriculum: Case Studies, in press.

39. Cited in Crawford, op. cit. note [illegible], pp. 218-219.

40. Faraday to E. Barnard, 23 July 1826, quoted in Williams, op.cit. note 8, pp. 105-106.

41. Ibid.

42. Ibid., p. 104. See also the epilogue to C. A. Russell, Crosscurrents: Interations between Science and Faith, Leicester, Intervarsity Press, 1985.

43. In 1858, for example, he argued that the purpose of a scientific

education is to enable "the mind to apply the natural power[s] through law[s of nature]" and so "conveys the gifts of God to man", 'On Wheatstone's electric Telegraph in relation to Science', Proceedings of the Royal Institution, 2, 1854-58, pp. 555-560, at p. 560.

44. This vision became the classical theory of the electromagnetic field. For its development see D. Gooding, ' "Magnetic Curves and the Magnetic Field: Experimentation and Representation in the History of a Theory', Gooding et. alii, op. cit. note 20, pp. 182-223.

45. See Williams, op. cit. note 8, pp. 471-74.

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