Faraday's Field Concept

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"When did Faraday have his field concept?" is a controversial issue in the Faraday literature, and one which is usually seen as an historical issue. However, before one can hope to answer the question of when, one must determine what his field concept was, and such a determination is a philosophical issue as well as an historical one. When I first set out to formulate what others say his concept was, I was surprised to find how difficult this is to do, especially as the protagonists are fairly explicit about when he had it. My contention is that this difficulty arises because there are actually three related questions involved in the problem of what Faraday's field concept was:

1. What was Faraday's conception?
2. What is required for a concept to be a 'field' concept?
3. What does it mean to say that someone 'has' a concept, i.e. what general form does the representation of a concept take?

In determining 'when' someone has a particular concept, these three questions need to be answered first. The failure to address (3) at all, coupled with the lack of a clear account of (2), has made the proposed accounts of (1) difficult to assess. This has made the issue of 'when' a subject ripe for classification as a 'dispute with no possibility of resolution'. My intention here is to show that, as the dispute presently stands, this is so; to shed some light on questions (2) and (3); to make a proposal for (1); and, finally, to make a contribution to this debate over 'when' and 'what'.

1 Five interpretations

The chief participants in the discussion are in order of appearance: Williams, Agassi, Berkson and Gooding. Let me begin by arranging them according to their answers on when Faraday had his field concept and what they take it to
be. In fairness to the protagonists I should say at the outset that there are significant differences between them in philosophical perspective and in their historical and philosophical method. A complete discussion of their views would have to take these differences into account. However, it is not necessary to do so here because my point is so fundamental that it applies to all of them irrespective of their philosophical and methodological differences. Also I want to make it clear that I am not a 'neutral commentator' (if there can be such a person!). I, myself, have made a contribution to the discussion. My works have appeared too recently to have been considered by others, and also I had not worked out what I am going to say here.  

As to when Faraday had his field concept, the positions divide into two camps: (a) somewhere between 1821 and 1832 and (b) around 1845–50. Agassi and Berkson fall into camp (a) and Gooding into camp (b). Williams is a bit more difficult to place and should be split into Williams 1 (1965) and Williams 2 (1975). 3 Williams 2 falls into camp (b). Williams 1 is not clear; his discussion of Faraday's interpretation of electromagnetic induction places him in camp (a), but his discussion of magnetic induction places him in (b). The difficulty arises because only Williams 2 is explicit about what he takes a 'field concept' to be.

I claimed earlier that 'what' comes before 'when', so let me now arrange the protagonists according to what they think Faraday's field concept was. This proves more difficult to do because only Agassi and Berkson are explicit about it. According to Agassi, Faraday's field concept was that of 'vibrations without a vibrating matter... a property without a substance and a motion without a substance to have the property to move around'. 4 Berkson claims that for Faraday, 'forces themselves are the sole physical substances' and the physical world was a 'continuous sea of force-substances, each point of which interacts with its neighbours only'. 5 It seems that Gooding believes that only Faraday's later views of magnetism contain a field concept. For Faraday, the magnetic field was 'points' or places characterised only by a certain strength of action'; while magnetism was an 'interaction of matter with a property in its immediate vicinity'. 6 Finally, Williams 2 intimates that Faraday's field concept was the 'idea that space, alone, can transmit force', and that he arrived at this 'leap of abstract thought' only after 1845 in connection with magnetic induction since there Faraday held that 'space itself carried the magnetic strain'. 7 What makes Williams 1 difficult to interpret is that early on he claims that Faraday interpreted electromagnetic induction as taking place through the action of lines of force and treated a line of force as an 'actual entity, somehow associated with matter, but independent of it'. He also holds that Faraday 'introduced a new concept' at this time (1832): the 'idea of the field of force generated in time and extending progressively through space'. However he claims in his later discussion of magnetic induction, that the 'foundations for field theory are to be found in Faraday's conception of magnetism as a 'strain in space, produced by ponderable matter in one way or another'. 8 The variety of answers to the question 'what was Faraday's field concept?' makes it difficult to provide a useful classification of the protagonists simply on the basis of that quest at the outset. That concept was we noted of what they take.

Question (2) is a concept and at first glance a reasonable to assume that the customary explanation of it is: 'a type of representation my discussion of questions such as these does not require that I shall not inconvenience the moment I will just by the protagonists.

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basis of that question. Rather this must be combined with question (2) raised at the outset. That is, to classify the positions taken about what Faraday's field concept was we need first to distinguish them on the basis of the prior question of what they take a 'field concept' to be. This proves quite interesting.

Question (2) is a prior question. If someone calls a particular notion a 'field concept' and attempts to say when it appeared in Faraday's work, it is reasonable to assume that they have a criterion of a 'field concept'. This cannot be the use of the term 'field'. Having a concept does not require use of the customary expression for that concept. It does require having a certain type of representation. Just which type of representation will be the subject of my discussion of question (3), but I should note here that 'having a concept does not require that we believe that representation to be true of anything. For the moment I will just try to determine which criteria for 'field' have been used by the protagonists.

It is surprising that despite the prior nature of a response to this question, it is difficult to ascertain their answers. Berkson is the only one who is explicit. He says that a 'field theory' is one which maintains that 'all action of one body on a distant body be carried by an intervening medium'. A 'field concept' is one which contains this notion of continuous transmission of action from one body to another through an intervening medium. What they say about the nature of Faraday's field concept and when he had it implies that Agassi, Gooding, and both Williams 1 and 2 hold that a 'field concept' involves the notion of 'properties existing in space'. How were these respective criteria selected? Only Agassi and Berkson tell us explicitly where theirs came from.

Berkson arrived at his criterion by focusing on the nature of the problem for which field theory was supposed to provide a solution: how action is transmitted to a distance. The field conception of forces developed as an alternative to the action-at-a-distance conception. It was distinguished by the idea of continuous transmission of action through an intervening medium. The central problems of this approach were to specify the nature of the process of transmission and to determine the nature of the medium. By concentrating on the metaphysical problem situation, Berkson selected his criterion to capture the key difference between field and action-at-a-distance metaphysics. This way of selecting the criterion allowed it to be formulated very broadly which in turn allowed for the possibility of different field concepts in different theories. In particular, both Faraday and Einstein could 'have' field concepts which nevertheless made quite different assumptions about the nature of the processes used in transmission of actions and about the nature of the medium of transmission. Use of this criterion, coupled with his analysis of Faraday's problem situation, required Berkson to be more specific about the unique features of Faraday's field concept. The lines of force are the medium and the means of transmission of force. Berkson thus makes his claims for the early appearance of this conception in Faraday's work on the grounds that Faraday made use of the lines as though they were real entities from the early period onwards.

Agassi selected his field-criterion from the 'modern', or 'Einsteinian' field
concept. A central feature of this is the existence of 'property' and motion without a substance. Agassi claims that when Einstein said this 'the public was merely puzzled; when Faraday said so the public was deeply shocked and incredulous'. But the question which needs to be asked is 'Did Faraday and Einstein really 'say', i.e., 'mean' the same thing by their field concepts?' Does Faraday's concept really need to be the same as that of Einstein's in order to be a field concept? Gooding and Williams appear to have selected their criterion from the 'modern' concept as well. Williams is the least clear about what he considers a 'field concept' to be, but the 'properties of space' criterion is implicit in his characterisation of Faraday's contribution to field theory. Use of this criterion creates the ambiguity in Williams 1 because he wants to attribute a significantly new concept to Faraday at the time of his analysis of electromagnetic induction. As he claims, 'It is not an exaggeration to say that a fundamentally new way of looking at physical reality was introduced into science in the second series of the \textit{Experimental Researches}'. But neither Williams 1 nor Williams 2 can call this new way of conceptualising electric and magnetic actions 'field' since 'action through lines of force' does not fit his implicitly modern criterion for 'field'. Only with respect to Faraday's late work on magnetism can a case be made for interpreting Faraday as having a concept which could fit this modern 'properties of space' criterion. In fact this is the crux of the dispute between Agassi and Williams over when Faraday had his field concept. This can be stated as follows: to make his point that Faraday had a field concept in his earliest researches into electricity and magnetism, Agassi's use of this criterion requires him to attribute more to Faraday than the evidence can support. The 'lines of force' were there at the beginning, but not as 'states of space'. This same criterion makes Williams withhold the attribution of 'field' from Faraday's early speculations, even though he wants to argue, along with Agassi, that a significantly new conception was introduced quite early in Faraday's work. We can now see, too, that the dispute between Berkson and Williams has been wrongly characterised as being about 'when' Faraday had a field concept; it is over 'what' Faraday's field concept was and what counts as a 'field concept'.

Finally, implicit reliance on the 'modern' criterion is also responsible for the difficulties I encountered in trying to provide a coherent interpretation of Gooding's position. For example, he analyses quite convincingly how Faraday used lines of force in his attempt to present a unified conception of all forces. Gooding even says that the lines of force were 'a physical theory of the field'. But he does not attribute a 'field' concept to Faraday until his work on magnetism; specifically, until Faraday was able to combine the 'lines of force' representation with the ideas of 'properties' or 'intensities' of 'points of action in space'. He, like Williams, is obliged to wait because these notions fit the 'modern' criterion in a way the 'lines' do not. Use of the 'modern' criterion seems to have allowed Williams and Gooding to avoid being specific about the features of Faraday's concept of field.

2 What is a field concept?

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I may be guilty of some simplification in my reconstruction of these positions, but my assessment of the situation is fair enough to show that something is amiss. In the first place most of the discussion about Faraday's field concept has taken place without the benefit of a prior analysis of what criteria are to be used in calling something a 'field concept'. This is often the case in such historical and philosophical analyses. Faraday's case is just a particularly good example. But something further is needed, something to which historians and philosophers of science have given little thought in their analyses of the formation and development of scientific concepts. They have failed to address the question: 'What is a "concept"?' This is question (3). An answer to this question is crucial in that not only do we have to know what the criteria are for a 'field concept' before we can attribute it, but we must also know what count as criteria. To ask 'at what point did X have concept Y' assumes not only that we have criteria for 'Y', but also that we have criteria for what it means to 'have a concept' at all. Such criteria specify what form the representation a concept takes.

*Having a concept: the classical view*

It is customarily assumed that a concept is represented by a 'definition', i.e. by a set of conditions each of which is necessary and all of which are jointly sufficient to define it. This 'classical' view goes back to Plato and Aristotle. It has influenced contemporary analyses of meaning through the work of Frege and Russell. It is so deeply engrained in our intellectual tradition that it has been acting as a tacitly assumed metatheoretical prescription for what scientific concepts should be like. There have been a few challenges to this conception. These have come mostly from those working in sciences concerned with classification, where classification by 'definition' has proved to be an obstacle. Also, within philosophy the later Wittgenstein criticised the notion of 'analysis by definition' so prevalent in analytic philosophy. But the import of his criticisms has only recently been appreciated. For the most part philosophers and historians have accepted uncritically the thesis that to have a concept is to have a particular set of necessary and sufficient conditions, and that when and only when these conditions are present are we truly entitled to call something a 'Y'. Having a concept is thus an all or nothing affair: if the conditions are not clearly present, as they are, for example, in Faraday's 1832 discussions of electromagnetic induction, then the most we can say is that he had a 'kind of' field concept or that he 'laid the foundations' for such a concept. Or, if we want to say that he really 'had it' earlier, then we must attribute the whole set of necessary and sufficient conditions to him at the outset.

This notion of a 'concept' underlies the customary view that concept-
formation in science is an act of ‘discovering’, ‘grasping’ or ‘acquiring’ concepts. This view makes it seem that concepts are sitting in a Platonic heaven, complete with their necessary and sufficient conditions, waiting for us to ‘find’ them. This view of ‘concepts’ is partly responsible for the famous problem of incommensurability of meaning between scientific theories, for if we ascribe different sets of necessary and sufficient conditions to ‘Y’ in a theory and to ‘Y’ in a later version of that theory, how can the ‘Y’s’ really be the same thing? Finally, there is the problem of how to select criteria that define a concept. Do we select them to match our modern concepts? If so, then we have to say not only that Faraday did not have a field concept, but that no one else did before Einstein, because no one used all of the modern criteria before Einstein. The alternative is to make Faraday’s concept seem identical with Einstein’s. If we say, on the other hand, that we choose our criteria from an examination of the problems the concept was designed to solve in the particular period, this would at least allow us to attribute concepts uniquely to individual scientists. However, we run the risk of having many different ‘field’ concepts throughout the history of science without being able to say how they are related because the use of the term alone is not sufficient to provide the historical connection.17

All this, of course, assumes that it is possible to state a set of necessary and sufficient conditions for a concept which will take in all historical uses of that concept. Yet it must be conceded that this is notoriously difficult, if not impossible, to do except in cases where scientists have explicitly defined their concepts. Central among the difficulties are: How do we distinguish between an ‘essential property’ and an ‘accidental’; i.e. between one which all instances must have and which most instances would have? And how do we account for the fact that in science, as in ordinary life, we often make use of ‘nonessential’ features in categorising something as ‘Y’. To take a simple example, a flying creature is usually categorised as a ‘bird’, but ‘flies’ is only an accidental or non-essential property since not all birds fly. In the case under consideration, these difficulties are apparent when trying to decide, for example, whether ‘is a state of space’ is essential to the concept of ‘field’ or not.

The prototype view of concepts

The question of whether such definitions are possible or even necessary, is a subject much disputed in contemporary cognitive psychology and in the new discipline of ‘cognitive science’ now forming at the interface of philosophy, cognitive psychology and artificial intelligence. Fodor, for example, argues quite convincingly against the possibility of definitions. His own claim that even such concepts as ‘electrons’ are innate, unstructured and ‘triggered’ by experience, is not useful in trying to understand scientific concept formation.18 However, it is possible to represent concepts in such a way that while undefinable, they are complex. One form of such a position has been called the ‘probabilistic’ or ‘prototype’ view. Although this is far from being a unitary

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position, the general claim of the view is that the representation of a concept is some sort of measure of a 'central tendency' of the properties of its instances. The representation of a concept is a set of 'family resemblances'. Particular instances vary in the degree to which they share these properties. The 'being' of a concept is related to the position Wittgenstein argued for in his critique of philosophical analysis. It has been made more explicit and been given wider scope by the work of Rosch, Mervis and others. On the probabilistic view 'resemblance' means that each feature of a concept is assigned a weight based on the total number of subject instances for which it is listed. The weight reflects the probability of the feature occurring in an instance. The more 'highly weighted' features present in an instance, the more 'resemblance' it has to other instances of the concept. For example, 'flies' would be a highly weighted feature of the concept 'bird', but since it is not an essential feature, its weight would be less than 1.0; while 'feathered' would carry the weight 1.0, since all birds have feathers. Thus, the features chosen to represent the concept are those which have a substantial probability of occurring rather than those deemed 'necessary' or 'essential'. Also, the possibility is open that the representation can change over time, i.e., that the weights can change or that new features can be added. This is necessary for examinations of the history of scientific concepts. The overlapping set of 'similarities' or 'resemblances' makes a concept into a unit, entitles us to call it the 'Y', and enables us to write its history.

The 'probabilistic' view of concepts is still a developing conception and is not without its problems. Yet when we examine how concepts arise, develop, and are used in scientific practice, we find that the 'probabilistic' view suits the scientific case better than the 'classical' view, which is customarily assumed. This new metatheoretical conception of concept fits well with analyses of the historical or 'developmental' dimension of meaning in scientific theories. It can allow for development, change and continuity in a way the 'classical' conception cannot. With it we can grant that there are a number of different concepts of electrical and magnetic action, each of which is a 'field' concept. 

3 When did Faraday have his field concept?

We are now in a position to return to Faraday. In this final section I shall outline a reconstruction of the nature of his 'field' concept and when he had it. I hope to make a plausible case for my interpretation. However, the philosophical 'housecleaning' was a necessary prerequisite to clear away confusions in the existing debate and to make it clear that my own interpretation of Faraday embodies a fundamentally different starting point as to what a concept is. In line with the notion of a concept that I propose to adopt, when we examine the features of what we take to be unquestionable instances of 'field' concepts, we see that certain features express 'central
tendencies" of these concepts. These include the notions that there are processes taking place in the region surrounding things such as magnets, conductors and charges and that the action of one body on another is through the continuous transmission of such processes from one to the other. What is it possible to say about Faraday with these salient features of the concept of 'field'? At the latest he had a 'field' concept when, in January 1832, he speculated that electromagnetic induction might take place through the 'cutting' of the lines of force. Two months later he speculated in a sealed note that

when a magnet acts upon a distant magnet or piece of iron, the influencing cause...

I think also, that I see reason for supposing that electric induction (of tension) is also performed in a similar progressive way.

He could not have made such a speculation without 'having' some features of a field concept. However, he did not have a fully articulated field concept at this point. The more specific features of his concept were still to be forged. This he did through further experimentation, analogical reasoning and speculation.

Saying that Faraday had a field concept at this point does not require us to suppose that he could substantiate, or even thought he could substantiate, the claim that electric and magnetic actions are actually field actions. One can 'have' the concept of a 'unicorn' without believing there are any. What he supposed in conjunction with his initial field concept was:

1. Electromagnetic induction is not an action-at-a-distance, but a new action.
2. This new action requires further study, which should provide a new understanding of electric and magnetic forces in general.
3. The lines of force would probably be shown to be essential to the description of the transmission of these actions.

'Having' a field concept at this point meant only that this was a possible way of conceiving the physical phenomena — one which might provide a better interpretation than the action-at-a-distance conception of forces, one which might turn out to be true and which would be fruitful to direct his research.

The major ingredients that went into creating his initial conceptions have been discussed by many philosophers and historians. These include his religious beliefs; his critical reflections on the nature of matter and of force (in which such notions as the interconversion of forces and the unity of all force are present as early as 1816-19); his familiarity with the views of Davy and Boscovich concerning matter; his familiarity with iron-filing experiments and with the notion of 'magnetic curves' to represent magnetism by Barlow and

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Faraday's Field Concept

Sturgeon's belief in the primacy of experimentation and the importance of trying to 'read' what is in 'the book of nature'; the problem of how to interpret the Oersted discovery and his own discovery of electromagnetic 'rotations'; and, finally, his early belief that the action-at-a-distance conception of forces is a 'speculation' and not a 'certainty'. These formed a network of beliefs and problems: theoretical, methodological, metaphysical, experimental and commonsense, which guided his experimentation and reasoning. In particular they led him to ask the question whether electromagnetic induction was due to the 'cutting' of lines of force.

As I said earlier the specific form of Faraday's field concept had still to be worked out. Just 'what' it was presents a problem because what Faraday said is ambiguous. He was hesitant about stating his views and he never completely articulated all the features of his field concept. The conception I have been able to reconstruct is basically similar to Berkson's. The specific features of Faraday's field concept, in its 'favourite' and most complete form, are that force is a substance, that it is the only substance and that all forces are interconvertible through various motions of the lines of force. These features of Faraday's 'favourite notion' were not carried on. Maxwell, in his approach to the problem of finding a mathematical representation for the continuous transmission of electric and magnetic forces, considered these to be states of stress and strain in a mechanical aether. This was part of the quite different network of beliefs and problems with which Maxwell was working.

The primary concept in Faraday's work is that of 'lines of force'. One aspect of this is a vectorial notion which he called 'representative lines of force'. The other aspect is a field notion which he called 'physical lines of force'. Both aspects are present from the time of his introduction of the cutting of the 'magnetic curves', which he quickly changed to 'curved lines of force', to his later explanation of how electromagnetic induction could take place (Table 9.1). Faraday did not make this distinction explicit until the twenty-eighth series of the Researches. In the vectorial notion, the lines represent the intensity and direction of the force in space. This notion is neutral between the field conception and the action-at-a-distance and even other possible conceptions of the nature of the actions. As Gooding has pointed out, this 'neutral' aspect was important to Faraday. It provided him means of representing the phenomena and of communicating his discoveries to others without implying a commitment to the physical existence of the lines. The physical aspect of the field concept contains the suggestion that the lines

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represent the actual ‘physical mode’ of the transmission of action. It was through the ‘physical lines’ that he hoped to construct a unified conception of all forces. This aspect of the lines was to provide him with the means for saying how force could be transmitted continuously through space. The tension between these two aspects or uses of lines (as representative and as real) is present from the beginning of his research. This is what makes him so difficult to interpret.\textsuperscript{32} He was hesitant to be more explicit about the ‘physical lines’ until his experiments on magnetic induction provided evidence strong enough to support their existence.

My case for this view of the \underline{specify} features of Faraday’s field concept depends primarily upon:

1. His use of experimentation in attempting to demonstrate the existence of the lines of force and the interconversion of forces via their actions.
2. The terms he used when discussing the lines (such as: ‘moving out’, ‘expanding’, ‘collapsing’, ‘bending’, ‘straining’, ‘vibrating’, ‘being cut’, ‘turning corners’) which was not simply metaphorical language.
3. The strong effect of the image of the lines on the reasoning and experimentation of one who believed one should read ‘the book of nature’ so literally.\textsuperscript{33}

I think that the influence of the visual image of the lines of force on Faraday has been underestimated. It played a crucial role in the construction of his field concept, in its initial formulation, in its development, and in its final form. The visual image provided Faraday with a means of exploring, both in thought and in experimentation, the possibility of action in and through space. He attempted to demonstrate that electrostatic and magnetic inductions took place along or through \textit{curved} lines of force. Their curvature provided an essential ingredient in his argument against their being actions-at-a-distance. At various times he tried to formulate a coherent conception of how the motions of the lines could account for all the forces of nature. The relationship between static and dynamic electricity might be founded in the expansion and collapse of the lines of force while magnetism might consist in a ‘vibration’ of the lines\textsuperscript{34} and might be connected with a ‘lateral repulsion’ between them. Electrostatic induction might take place through the action of ‘contiguous particles’ along \textit{curved} lines of force and magnetic induction by means of ‘conduction’ of the lines with varying degrees of ease in different media. Light and gravitation could be the result of a ‘shaking’ or ‘vibration’ of the lines. Even matter itself might be nothing more than point centres of lines of force. This view was similar to, though hardly identical with that of Boscovich.\textsuperscript{35}

The image of the lines makes them discrete. The influence of discreteness is apparent in his formulation of a quantitative relationship between the ‘number of lines’ cut and the intensity of the induced force in electromagnetic induction. ‘Number of’ is an integer, while ‘field’ intensity would be represented by a continuous function. We see the influence of the image also in the analogies he selected to express what he meant, in particular, his choice of
sion of action. It was a unified conception of the means for saying that in space. The tension native and as real) is what makes him so difficult. If the "physical lines" evidence strong enough tradition's field concept illustrate the existence of their actions as: "moving out", "cutting", "being cut", "piercing". The reasoning and the "book of nature" of force on Faraday's inclusion of his field in its final form. The both in thought and through space. Electric inductance took nature provided an actions-at-a-distance. The conception of how the are. The relationship is the expansion and at a "vibration" of motion" between them. the distinction of "contiguous action by means of different media. Light action is the lines. motion of lines of force. hat of Boscovich. The one of discreteness is the electromag- netic intensity would be of the image also in- cular. his choice of other "line-like" phenomena such as rays of light and heat, rings in water and conduction through wires.

Some problems of interpretation

With the "field" aspect of the lines of force there is an unresolved tension between the physical lines as the paths of transmission of the action through space and the physical lines as the vehicles which transmits the actions. This ambiguity is responsible for some of the confusion surrounding Faraday's position on the aether. If the lines simply mark out the geometrical path of the motion, then we need to ask what they are paths in. They could represent states or processes in an "aether", which Faraday does allow, although he emphasised that such an aether would be quite unlike "ordinary" matter. Or, they could just as well be paths in "mere space". The conception of lines as "vehicles" transmitting the action does not necessarily preclude the possibility of an aether but really makes it unnecessary. The lines themselves transmit all the forces of nature and connect every "particle" with every other so that its sphere of influence is "the whole of the solar system". There is no need for an additional aether. Whether we choose to call this field of force "aether" was, he thought, more a matter of semantics than of physics. The unresolved ambiguity between "paths" and "vehicles" stemmed from the fact that, his experiments on unipolar induction and with the search coil notwithstanding, Faraday was never able to demonstrate conclusively the independent existence of the lines themselves.

A further issue, related to this last point, needs discussion. This is the distinction Faraday made between electrostatic lines of force and magnetic lines. He claimed that the electrostatic lines exist "by a succession of particles", while the magnetic lines exist by a "condition of space free from matter". This distinction should be considered as a distinction in evidence, rather than in kind. Faraday felt that he had some convincing evidence that magnetic lines of force existed in space independently of matter. But he had no comparable evidence that electrostatic lines existed independently of the particles of a dielectric medium. He had no observational evidence for his lines of force conception of particles. Here his argument lay in his demonstration of the essentially dipolar nature of magnetism. Wherever a magnet exists, there must be lines, since they are what connects the poles of the magnet. In fact he thought that the polarities of a magnetic system reside in the lines themselves. Further, since magnetic induction does not involve polarisation of a medium he could make a more convincing case for the magnetic lines of force being the "vehicles" of transmission than for electrostatic induction, which does involve polarisation. So, in the case of electrostatic induction he felt able to argue only for action in curved lines (i.e., curved paths) by means of "contiguous particles". To do full justice to this conception, we must interpret "particles", even in the electrostatic researches, in terms of a lines of force conception of them.
Faraday did not formulate the views expressed in his 1844 'Speculation' simply in response to Hare's criticism. As he maintained, there was no inconsistency in his notion of action through 'contiguous particles'. Hare failed to grasp the meaning Faraday attached to the 'words of the language of electrical science'. The roots of this 'speculation' lay in his earlier work on electrochemistry and electrical conduction. This substantiates my claim that the electrostatic lines of force were not different in kind from magnetic. All that existed for Faraday were lines of force, the variety of forces of nature being nothing more than their possible motions. However, a clearer formulation of this position appeared in Faraday's 1846 'Thoughts on Ray-Vibrations'.

4 Conclusion

I have argued first that the question of 'when' Faraday had his field concept requires that we say 'what' it is. This involves three questions: What is a 'concept'?; What is a 'field' concept?; and What was Faraday's 'field' concept? I also argued that the metaquestion 'What is a “concept”?' is of considerable importance not only here, but to historical and philosophical analyses of the history of scientific concepts generally. I have argued that a 'probabilistic' view of a concept fits scientific situations and historical developments far better than the generally assumed 'classical' view. Finally, I have attempted to supply answers for 'when' Faraday had his field concept and 'what' it was. This was not done solely on the basis of the new conception of 'concepts'. However, that conception does allow us more flexibility in interpreting the historical data. With it we can attribute a 'field' concept to Faraday quite early, without having to attribute to him, either all the features of his mature concept or those of the modern conception. We can show that its specific features developed over time and that it had features quite unlike other field concepts, yet still maintain that it is connected with other field concepts; in particular with the modern one.

Notes

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17. Faraday did not even use the word ‘field’ until 7 November 1845, Diary, 4, 7979; Faraday (1846b), 2247. In Faraday (1851), 2806, he defined ‘field’ in terms of ‘lines of force’. See Gooding (1981), 239 especially note 35.
22. Faraday (1832b), 217ff.
26. Cantor (this volume).
27. Williams (this volume) and Gooding (this volume).
30. Faraday (1852a), 3075, 3175 Nersessian (1984b), Chapter 3.
32. Other reasons are discussed in Gooding (1975, 1978) and Cantor (this volume).
36. He did not take his experiments on unipolar induction and with the search coil as providing conclusive demonstrations of the independent existence of the lines. Faraday (1832b), 220 and Faraday (1852a), 3070ff.
37. Faraday (1838a), 1–64 and Faraday (1852b), 3258.
38. This is argued in Gooding (1978). Hare (1840). Faraday (1844).
40. Faraday (1846c).
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