The Fields of Light

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> *Socrates:* Then just take a look round and make sure that none of the uninitiate overhears us. I mean by the uninitiate the people who believe that nothing is real save what they can grasp with their hands and do not admit that actions or processes or anything invisible can count as real.
>
> *Theaetetus:* They sound like a very hard and repellent sort of people.
>
> *Socrates:* It is true, they are remarkably crude.
>
> Plato, *Theaetetus* (155e)

Those who reflect on physics often express a certain dismay at what seems the aridity of the "new science" that began with Descartes's project of a mechanical understanding of Nature. Granted that its results are imposing and powerful, the question remains: What is *interesting* about it? Here *interest* bears its original economic sense, as when capital yields interest. In this usage the Latin *interesse* signifies the emergence of new and different accrual to the initial deposit of an idea. It denotes something novel, even surprising, proceeding from given premises. This essay will try to show how the attempt to describe Nature solely in terms of palpable matter leads, through its own inner development, to a new understanding that transcends matter. To put it tersely, matter is not material. It calls forth a new mode of being, the field, which ultimately eclipses matter itself.

The question concerning the nature of light reveals this shift with particular clarity and was in many ways also the ground for its occurrence.

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Lucretius can stand here as an exponent of the initial thrust of these accounts. Following Epicurus, Lucretius suggests that an object sends out films of atoms which detach themselves from its outer surface and float outwards.[1] Some of them, quite by accident, encounter the eye and give rise to the visual image. Others, impinging upon ears or nose, give rise to sounds or smells. This account may be contrasted with the hypothesis Plato entertains that the eye itself sends out rays whose encounter with the object constitute vision.[2] The *activity* of the eye in Plato's account is essential. For Lucretius the eye is a *passive* receptor that converts the impinging atoms into the visible sensation. Thus he explains vision in terms of traveling material substances.

His account is in many ways similar to the account Newton offers much later in his *Opticks*. However, for Newton the light is not simply atoms from the surface of the body that enter the eye. He speculates that the rays of light are "very small bodies emitted from shining substances."[3] The light is distinguished from the shining substance that emits it. As Newton writes:

> The changing of Bodies into Light, and Light in Bodies, is very conformable to the Course of Nature, which seems delighted with Transmutations. . . . Eggs grow from insensible Magnitudes, and change into Animals, Tadpoles into Frogs, and Worms into Flies. . . . And among such various and strange Transmutations, why may not Nature change Bodies into Light, and Light into Bodies?[4]

It is noteworthy that Newton chooses these organic images of transformation in describing the behavior of light rays, themselves composed of inorganic bodies regulated by mathematical principle.

A crucial similarity to Lucretius nonetheless remains: Light is "very small Bodies" traveling until they impinge upon the eye, which is a material structure also. Many powerful conclusions flow from this approach. Color, for Newton, results from the different sizes of the light particles. Refraction results from the acceleration of these particles as they move from air into glass or water. A comprehensive account is formed that seems to encompass all known optical phenomena. Yet, as Newton admits, the only sure account is really a mathematical description of the phenomena which leaves largely unknown the underlying physical reality, just because he will "feign no hypotheses" concerning the forces he describes in the theorems. In his Queries, however, Newton suggests that particles of light will now most readily account for the theorems he proved earlier when speaking of rays of light. These rays are mathematical entities which he had discussed as such without needing to specify their nature. For Newton, there is a difference between the assurance with which he speaks of the mathematical properties of the rays and the diffidence with which he speculates that the rays are composed of particles.

But, as Newton starts to speak of the manner in which glass or water affects the rays so as to cause the appearance of refraction, he remarks that these substances "act upon the Rays of Light at a distance . . . and this Action and Re-Action at a distance very much resembles an attractive Force between Bodies."[5] He makes similar assertions elsewhere that the force of gravity also and perhaps all forces between bodies seem to act at a distance. That is, one body can affect another, distant body in a manner that simply depends on the distance between them. For Newton, it would go too far, at this stage at least, to assert that such a force must necessarily *travel* somehow between the bodies. Mathematically, it seems to act at a distance, and we should not then "feign the hypothesis" that such action at a distance then implies transmission of the force passing in some describable way through the space intervening between the two bodies.

So in his public writings Newton felt that describing gravitation or the action of glass upon a light ray as action at a distance was all he could do with full circumspection. But privately Newton felt the necessity to go further. In a celebrated letter to Bentley he wrote that

> it is inconceivable that inanimate brute matter should, without the mediation of something else, which is not material, operate upon and affect other matter without mutual contact, as it must do if gravitation, in the sense of Epicurus, be essential and inherent in it. . . . That gravity should be innate, inherent and essential to matter, so that one body can act upon another at a distance, through a vacuum, without the mediation of anything else, by and through which their action and force may be conveyed from one to another, is to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it.[6]

In some of his Optical Queries Newton tried to account for gravitation in terms of the pressure of some medium, but much of this work he left unpublished because, as Maclaurin wrote, "he found he was not able, from experiment and observation, to give a satisfactory account of this medium, and the manner of its operation in producing the chief phenomena of nature."[7] So for Newton, at least, the attempt to advance the Lucretian notion that light is simply a stream of small bodies led to the need for some sort of mediation of the forces acting between bodies. Newton felt that such mediation required some sort of medium, and that medium baffled him.

In reaching this impasse, Newton considered and rejected the suggestion of Huygens that presumed the existence of a universal medium or aether, and described light as waves traveling through this medium, much as water waves represent a state of vibration which passes through the medium of water.[8] Huygens imagined the space between bodies as packed with small, hard particles of equal size. When a body began emitting light at some point, he considered that these ether particles would transmit a shove much as a pool table packed with billiard balls would transmit an impulse imparted to some ball at the edge of the table.

But Newton replied:

> A dense Fluid can be of no use for explaining the Phaenomena of Nature, the Motions of the Planets and Comets being better explained without it. It serves only to disturb and retard the Motions of those great Bodies, and make the Frame of Nature languish . . . so there is no evidence for its Existence, and therefore it ought to be rejected.[9]

Such a dense medium is for Newton the prime example of a "feigned hypothesis," as he terms it, which turns from the appearance of empty space to the daring and questionable supposition of an invisible and dense ethereal medium pervading space. Thus for Newton the notion that rays of light are "very small Bodies emitted from shining Substances"[10] is vastly preferable.

Though he rejects the dense medium he felt was necessary for Huygens's theory, Newton nonetheless did not hesitate to argue for a "much subtiler Medium than Air, which after the Air was drawn out remained in the Vacuum."[11] He argues that this subtle, rarefied medium would give way before the passing planets and not disturb their orbits, and its varying density would explain the refraction of light and the transmission of heat. All this seems less paradoxical when Newton asserts that his ethereal medium is not like that of Huygens, "which fills all Space adequately without leaving any Pores, and by consequence is much denser than Quick-Silver or Gold."[12] The resistance of Newton's ether would be inconsiderable, he argues, because it is so rarified. There are void spaces between the ether particles which permit Newton's ether to be more or less rarefied or compressed. Those void spaces allow his ether to slide around the planets without hindering them, whereas Huygens's picture fills space with particles densely packed with no space between them.

Thus one comes to see that Newton's ether is not in his eyes a feigned hypothesis, because it seems to him unavoidable in explaining the refraction of light and yet does not impede the motion of bodies. But that leaves him in the quandary about how forces act between the particles of material bodies. For Huygens, bodies act by direct contact, and not at all at a distance. For Newton, it would seem that, finally, bodies can only act at a distance, since he does still require the empty spaces between bodies. But, as Newton himself admitted in the letter we cited earlier, such a notion of action at a distance is disturbing and mysterious. To quote him again, "It is inconceivable that inanimate brute matter should, without the mediation of something else, which is not material, operate upon and affect other matter without mutual contact . . . ." These words, "the mediation of something else, which is not material," are thrown into even higher relief. Newton seems to understand that this mediation is not simply by means of a material medium. That is, if for instance we consider that two bodies exert forces on each other by sending little particles out, we are still left with the problem of how these little particles act, by direct contact, or at a distance. So there is no escape from our problem of how bodies exert forces on each other simply in postulating even smaller particles that somehow accomplish this mediation. Eventually, we must face the question: action at a distance or direct contact?

Huygens's notion of direct contact would seem satisfying except for Newton's objections and the further problem of the unyielding hardness of the particles that is required. For imagine two bodies coming into contact. If they are not absolutely rigid and hard, there is a certain delay from the moment of first contact and the resulting recoil. That implies a certain *mediation* of the directness of contact. Even worse, when is the exact moment of contact? The edges of the bodies would have to be perfectly sharp and square for one to be able, even in the imagination, to assign a true moment of contact, rather than a certain interval during which they contact each other and interact. Perhaps our problem would disappear if we were to treat each body as a Euclidean point, much as Newton teaches us to do in the *Principia.*[13] But it is very disturbing to think that the force only springs into existence in the moment of contact, when the two points coincide. For if two points coincide, they are really not two points, but one point. And how can one point exert a force on itself? Or what sufficient reason would give the magnitude of such a force, exerted by a dimensionless body at no distance? On the other hand, if the two points do not coincide, our supposition of force as direct contact would say they cannot exert any force on each other! As if this were not difficult enough, our picture of material bodies as points, which we required in order to speak exactly of contact between bodies, is really a mathematical representation only, as Newton says. The bodies we are familiar with are irregular and rough and hence couldn't simply be treated as points, even if the argument about points would have worked! Another way of putting this is that even if I envision a body as composed of point-like atoms, those points could never touch.

I am left with the strange and disquieting conclusion that no material bodies have ever touched, in the sense that I cannot find the moment of contact even if I picture the bodies as points or composed of points. Perhaps difficulties such as these moved Newton to speak of action at a distance, since no simple hypothesis of action by contact will do. Yet it was the inscrutability of action at a distance that made him speak of "the mediation of something else, which is not material . . . ."[14] This mediation offers a reasonable escape from our dilemma. If action by contact is fallacious, then the mediator cannot be material but must be "something else." This leads to the conclusion that the natural philosophy of matter cannot remain complete without invoking a mediation that is not material. So matter must point beyond itself.

The full implications of such a statement must rest on inquiry into what we mean by "matter." The rough sensual description of matter as something weighty, and able to be touched, seen, and smelled, obviously begs the question, since we must refer to organs of sensation or measurement which are themselves material. By speaking of it in terms of interactions between material objects and material measuring instruments we still beg the question of matter (by itself, in itself). In a celebrated passage, Newton writes that

> All these things being consider'd, it seems probable to me, that God in the Beginning formed Matter in solid, massy, hard, impenetrable, movable Particles . . . and that these primitive Particles being Solids, are incomparably harder than any porous Bodies compounded of them; even so very hard, as never to wear or break in pieces; no ordinary Power being able to divide what God himself made one in the first Creation.[15]

What these particles are, or are made of, would seem almost an inadmissible question, if they are to be the primitive, most basic constituents. Yet if they are not simple points and have some size, we surely must entertain the question of what forces between the points of these atoms make them so extraordinarily hard. The atom seems to dissolve into a constellation of immaterial forces. Even were the atom utterly dimensionless and point-like, we would have the pregnantly absurd situation of matter, which presumably occupies space, occupying no space at all! And if the atom is extended in space, we can still speak of the distance between certain points within the atom, or the forces between these points. But we have just shown that there can be no matter simply at a point. If we cannot say that there is matter at any point, where then is it?

Our problem reflects an ambivalence in Newton's own thought between the material, physical world and the mathematical principles, which speak of forces that are not material but mathematical entities. In this mathematical view mass itself is a pure magnitude and not palpable stuff. In speaking of hard particles Newton means, I suppose, to return to the world of experimental appearance from the world of mathematical principles. Even though he wishes to show that the mathematical principles guide and describe the observed motion of bodies perfectly, yet the language and rhetoric of mathematics jar against that of "stuff" and matter. It was Kant's insight at this point to say that what we can know of matter is force and only force. To attempt to speak of matter in itself, beyond the character of the forces experienced, is to ask to know something beyond our capacity. Kant goes on to argue that an absolute and empty space through which Newton's action at a distance might act is "nothing at all belonging to the existence of things."[16] These powerful observations were to a great degree ignored by practicing scientists of the time, though it must be said that Kant's teaching of the primacy of forces in natural philosophy had an immense influence through the German *Naturphilosophie.* I would suggest that the heart of field theory, and even of relativity and quantum theory, lies implicit and foreshadowed in Kant's deep insights. Indeed, I do not think that modern natural philosophy has yet by any means exhausted the depths he pointed out.

Let me turn from Kant and return to Newton's thought that it does make sense to speak of "solid, massy, hard, inpenetrable particles." What is it that makes us so sure that "brute inanimate matter," as Newton calls it, really must be part of our conception of the world? We seem to pay respect to our sensations and give them credit, as it were, by referring them to a thing, matter, which is the true source of smells, tastes, and sights. But our argument has led us to see the solid mass of matter dissolve into a web of interacting forces. Why do we continue to speak simply of matter? Perhaps because it would seem like an insult to our senses if we denied them an external source and origin.

Nevertheless, even with the greatest enthusiasm for a notion of matter and of primitive particles such as Newton had, we have been led to consider a maze of forces as the key to the behavior of matter, as if matter—even if we should cling to this notion—were finally at the disposal of the forces and wholly guided by them. Whether we begin with streams of light particles, as Newton does, or with an undulating medium, the mystery of light is contained in that non-material mediation which is the actuality of the reception of the hypothetical light particles or of the hypothetical wave. Finally, there is always a gap across which a leap, an act of mediation, must occur.

It is here that Aristotle helps, in a way that shows that the interweaving of these themes is not merely historical but even more richly complex. I present it here intentionally out of chronological order to stress the timelessness of the insight. In *De Anima* Aristotle has much to say about vision that speaks eloquently to the point we have reached in our inquiry. Light, he says, is "the activity [*energeia*] of the transparent in that [it is] transparent."[17] He, too, understood that it is in the transparent, seemingly empty, gap that the true nature of light lies. Light is "neither fire, nor in general any body, nor an emanation from any body (for in that case it would be a body of some kind), but the presence of fire or something of such kind in the transparent."[18] He goes on to explain that, since in his view there are no void, empty spaces, there is no space for another body to enter in. So light cannot simply be a body, for it would have to be at the same place as other bodies (the air, for instance) at the same time. Rather, light is *energeia*, a word closely related to work and activity, and is the particular activity of the transparent medium he calls *metaxu*, literally the "in-between." It is not this *metaxu* that is light, but rather light is a kind of activity or energization which is perhaps best expressed by the way Aristotle speaks of *energeia* elsewhere throughout his works. One gets the sense of maturity, of coming to full bloom, of a process or an organism coming into its full estate. Aristotle also observes that "matter is relative to some thing," signifying that matter exists in a state of *relation* to form and purpose.[19] He does not consider that it exists apart from these larger relations.

In the case of light, Aristotle speaks of a state of being energized and active which applies to this transparency between seer and object. This energization of the in-between zone seems to tally with the sort of "non-material mediation" Newton was groping for. Yet there are many divergences also: Newton's light particles travel in a void, while Aristotle's light is the energization of a region replete with substance, not void anywhere. In that respect Aristotle seems much closer to Huygens's picture of a dense medium through which vibrations pass. So Aristotle's view emerges as an immensely suggestive synthesis, before the fact, of Newton's play of forces (which he might understand as a sort of *energeia*) and Huygens's vibrating medium.

This constellation of accounts seems in want of further development, and indeed it is Newton who finds the crucial issue. In criticizing Huygens he remarks that if light were wavelike motion propagated through a fluid medium, like water waves, it would necessarily follow that light should not simply travel in straight lines but rather bend around obstacles just as water waves do. As he puts it,

> The Waves on the Surface of stagnating Water, passing by the sides of a broad Obstacle which stops part of them, bend afterwards and dilate themselves gradually into the quiet Water behind the Obstacle. The Waves, Pulses or Vibrations of the Air, wherein Sounds consist, bend manifestly, though not so much as the Waves of Water. For a Bell or a Cannon may be heard beyond a Hill which intercepts the sight of the sounding Body, and Sounds are propagated as readily through crooked Pipes as through straight ones. But Light is never known to follow crooked Passages nor to bend into the Shadow. For the fix'd Stars by the Interposition of any of the Planets cease to be seen.[20]

This would seem a critical problem, since Huygens also admitted that light seems to travel in straight lines, and he had to resort to rather tortuous and unconvincing arguments to make his light waves not seem to do just what Newton argued they might do. Thomas Young first observed phenomena that indicated that light does not simply travel in straight lines but indeed bends around obstacles just as Newton said that it would do if it were a wave. This seemed to be the moment of triumph for Huygens's notion of a vibrating medium, and of disgrace for the Newtonian picture of light as a particle. In the century following Young's first experiments, the great drama of the elaboration of the theories of electricity and magnetism unfolded, led by Faraday and Maxwell, leading to a notion of light as a wave composed of electric and magnetic fields.

What are these fields? In them may be the reappearance of Aristotle's notion of *energeia*, its phoenix-like rebirth after centuries in which Aristotle's physical thought was usually said to be simply wrong, dead, and useless. This may be an example of how the process of thought does not unfold simply historically, the later views a product of what preceded them. Aristotle grapsed an essential facet of the problem of light in a way one appreciates more fully after reading Newton, Huygens, and Maxwell.

The term field in this sense was in essence created by Maxwell, but it emerges from Michael Faraday's earlier discussions of what he called lines of force. The nuance is, I think, crucial and reveals much about Faraday and Maxwell. The son of a blacksmith, and himself a bookbinder's apprentice, Faraday became a laboratory technician at the Royal Institution in London. Through many years of reading and ceaseless experimentation, he became a great luminary of European science.

He hated the term "physicist," which had only recently (1830) been coined by Whewell, and wished to be, and to be called, a philosopher, an "unmathematical philosopher"[21] to boot, quite uneducated mathematically and separated from the great tradition of mathematical physics that Newton inaugurated with his *Principia*. Faraday wrote no treatise as Newton and Maxwell did, but left instead his episodic *Experimental Researches* and his *Diary*. As Thomas Simpson has written, these works were

> not theory, but a vast weaving and unweaving of suspected powers, a process of continual discovery and identification, a great, highly unified formulary for the production and classification of effects . . . . [He] is the great 'discoverer'; the paradigm for Faraday is Odysseus rather than Euclid: in a sense he, too, travels from land to land, reporting wonders, guided by legend and myth, rumor or divine love. For Odysseus, the dominant desire is to see men's cities and to know their minds, and to gather all this together in the return to Ithaca. For Faraday, it is to investigate all the powers of nature and to unveil them as esssentially one in the lecture hall on Albemarle Street.[22]

Faraday was the most practical of men and intensely attentive to the vivid detail of experimental phenomena. He was a true virtuoso of experiment, insightful and indefatigable, and endlessly inventive. He grew up with notions of electricity and magnetism as palpable and ponderable stuff. Yet this immensely practical and clear-sighted man gradually convinced himself that the true seat of electric and magnetic effects is the space surrounding electrified or magnetized bodies, whether that space be filled with some noticeable substance like air or seemingly empty.

Strange, is it not, for such a man to pass from the palpable bodies he sees before him to consider instead the impalpable, empty space between? Yet it was many experiments that led him thither, perhaps the most pregnant being one of the simplest. Consider a magnet upon which have been sprinkled iron filings. These filings seem to align as if to outline invisible lines that characterize the magnetic force. The presence of the filings makes the force visible. Does it not seem inescapable, thought Faraday, that these same lines of magnetic force are present even before the filings have been introduced? Many other considerations, particularly the characteristic curvatures of the lines, moved Faraday to speak of the lines as "physically real."[23]

Further, he felt persuaded that there was no need to speak of electric or magnetic fluids or substances, that these lines of force were the real, the essential seat of electric and magnetic phenomena. He writes that "as magnets may be looked upon as the habitations of bundles of lines of force, they probably show us the tendencies of the physical lines of force where they occur in the space around."[24]

Faraday seemed happiest with a vision in which his physical lines of force arch through space, without even ether, invisible yet physical. His friend Maxwell, in an admiring letter, describes this vision: "You seem to see the lines of force curving around obstacles and driving plump at conductors, and swerving towards certain directions in crystals, and carrying with them everywhere the same amount of attractive power . . . ."[25] In many parts of his great *Treatise*, Maxwell frankly admits his debt to Faraday, making us feel that he had indeed realized Faraday's vision in a mathematical way that Faraday himself could not have achieved.[26] In his letter to Faraday, Maxwell goes on to say that

> you are the first person in whom the idea of bodies acting at a distance by throwing the surrounding medium into a state of constraint has arisen, as a principle to be actually believed in. We have had streams of hooks and eyes flying around magnets . . .; but nothing is clearer than your description of all sources of forces keeping up a state of energy in all that surrounds them . . . .[27]

Even this frank praise reveals something about the two men. Faraday's lines of force become, for Maxwell, the "state of constraint of the surrounding medium," which he feels has a mathematical form and which he calls a field. Those physical, yet immaterial, lines of force Maxwell understands as states of a medium and the fields are the states of polarization of that medium.

Though Maxwell describes himself as translating Faraday's ideas into a mathematical form, the differences between the two men are extremely interesting. Writing to the great theorist Ampère, Faraday himself remarks that

> I am unfortunate in a want of mathematical knowledge and the power of entering with facility into abstract reasoning; I am obliged to feel my way by facts closely placed together so that it often happens I am left behind in the progress of a branch of science, not merely from the want of attention, but from the incapability I lie under of following it, notwithstanding all my exertions. . . . I fancy the habit I got into of attending too closely to experiment has somewhat fettered my power of reasoning, and chains me down; and I cannot help, now and then, comparing myself to a timid ignorant navigator who, though he might boldly and safely steer across a bay or an ocean by the aid of a compass which in its action and principles is infallible, is afraid to leave sight of the shore because he understands not the power of the instrument that is to guide him.[28]

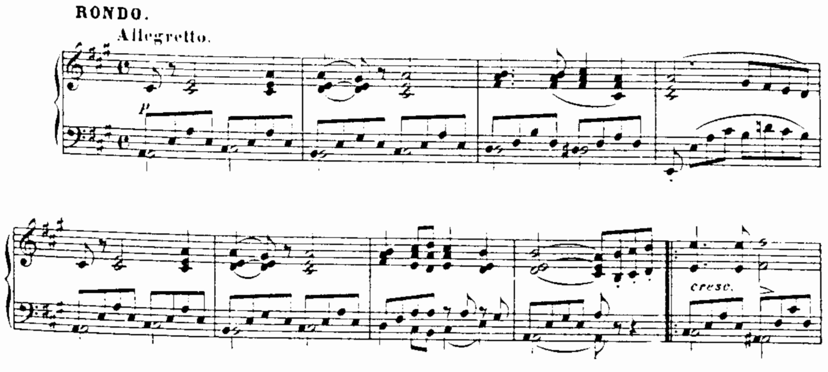
Faraday wrote to Maxwell, "I was at first almost frightened when I saw such mathematical force made to bear upon the subject, and then wondered to see that the subject stood it so well."[29] There is gentle irony here, as well as respect for the power of the mathematical symbols Maxwell was forging. Also, Faraday maintains a certain pride in the integrity of his own progress, even as he self-deprecatingly calls himself a "labourer." He knew the value of his labors, or at least felt serenely confident that posterity would sift the gold from the dross. Yet there is also the note of a wistful Moses, who sees the promised land from afar and recognizes that he will not himself enter into the fullness of it.

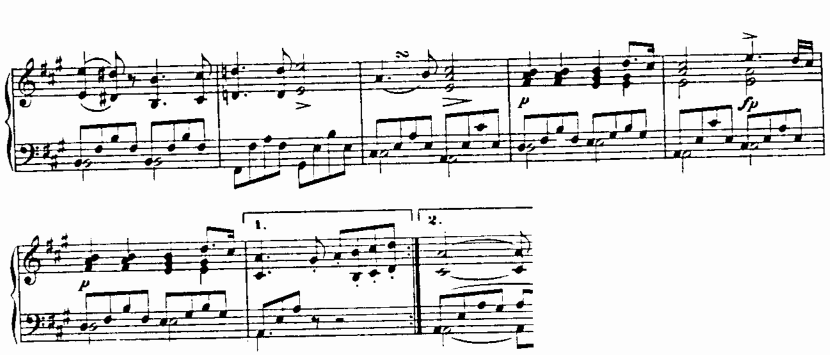
In the case of Faraday and Maxwell, the promised land was the fields of light. It was left for Maxwell, through the power of his mathematical symbols, to discern in exact mathematical detail how light might be the coupled undulations of electric and magnetic fields, how moving a charged body sends a wave down their lines of force, a wave we can perceive as light. Yet I must emphasize that, in his own way, without mathematics, Faraday found these fields of light. He says that "the view which I am bold to put forth considers, therefore, radiation as a high species of vibration in the lines of force which are known to connect particles. . . . It endeavors to dismiss the ether, but not the vibration."[30] It seems to me that this discovery may be more wonderful than Maxwell's mathematical deduction and translation, in the way that one admires the pioneer explorer even more than the settlers that follow him. But there are excellences in both men that should be savored. Together they saw how the field leaps free of its source and can travel through boundless space.

Maxwell followed Faraday also on a further flight of speculation. If indeed these lines of force flex far from any body and if their state of tension is the true seat of the electromagnetic interactions, perhaps the notion of electric charge as a sort of fluid or simple material substance should be abandoned. The true actuality of electricity, magnetism, and light lies in the mediating fields; matter and charge dwindle and disappear from sight. At first Maxwell tried to think of "empty space" as filled in imagination with gears and idle wheels, an elaborate mechanical structure that helped guide his understanding as he wrought his equations.[31] Though he cherished his gears and wheels, when he came to write his *Treatise* he omitted all mention of them, now relying on the finished mathematical structure. Maxwell continued to believe that there might be a physical ether of which the fields were states of vibration, even though he ceased describing it in simple mechanical terms. Here the practical Faraday is more visionary still, for Faraday understood the lines of force as themselves sufficient, without any need for an ether to give them substance and habitation. The lines of force, the fields as Maxwell thought of them, are all that is. The great project of the purely material and even mechanical understanding of Nature has demanded these immaterial mediators which at last have eclipsed matter.

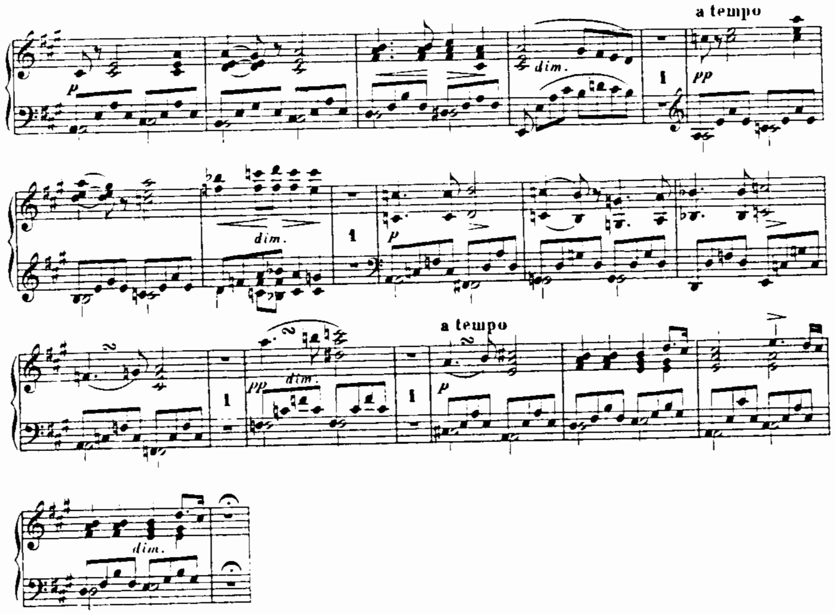
It does seem very odd simply to discard matter in favor of ghostly fields. Here it is helpful to think of music. Victor Zuckerkandl has written that "music is movement of tones in dynamic fields."[32] Music is indeed in no single note, but rather it is in the web of interrelationships that can be aptly termed a field. That is, the music is also between the notes. There is no silence in the sense of a void, utterly blank. The silence that precedes a piece of music is part of it, as one realizes when watching the different silent gestures a conductor uses to give the up-beat that precedes the sounds. I suppose here is Aristotle's insight regarding the absence of utter physical nothingness in the world, of sheer emptiness. If we take either Faraday's or Maxwell's account, there is not nothingness anywhere, for the field is there. Aristotle has shown us how *energeia* must emerge from a prior state of preparation, of *dynamis*, and not from nothing. The contemporary quantum theory of fields has argued, in extending Maxwell's mathematical theory, that sheer emptiness is self-contradictory.[33] This agrees deeply with Aristotle and gives the sense that the seemingly empty space, the silence, is the heart of activity, of music.

At times this vital silence is brought before us with particular intensity. The silences of a great work of art are the seat of its mysterious power and deserve our closest attention. Let me give you an example. Schubert, in his next-to-last piano sonata, in A major (D.959), concludes with a rondo based on a theme he had written when he was twenty, and which also became the song "Im Frühling." Here is the theme as he first presents it at the beginning of the rondo (measures 1–16):





Here is how Schubert shows us this theme at the end of the movement, after many variations and vicissitudes (measures 328–347):



The silences form a final revelation of the inner life of the theme. In each silence something immense happens. We are plunged into the field of force that is the music, when the music stops—as it would seem—and yet evidently does not stop. It is like that when we look at the light which only exists in and by virtue of the so-called "empty space." Our experience, then, is a field.

Randomly bumping particles and mechanisms do not hold much prospect of touching the sort of beings we are, but speaking of fields is more like us. A field is most of all a state of inter-relationship which has an inner integrity. In grasping such connections, the human mind shows its affinity with the field.

Perhaps in closing we should recall Einstein's first encounter with an object suspended in a field—a simple magnetic compass which his father gave him at four or five years of age.

> That this needle behaved in such a determined way did not at all fit into the nature of events, which could find a place in the unconscious world of concepts (effect connected with direct "touch"). I can still remember—or at least believe that I can remember—that this experience made a deep and lasting impression upon me. Something deeply hidden had to be behind things.[34]

Recalling this in later life, he also remembered how he "trembled and grew cold."

Notes

1. Lucretius, *De Rerum Natura* IV, 42 ff.
2. Plato, *Theaetetus* 156d.
3. Isaac Newton, *Opticks* (New York: Dover, 1979), p. 370. This and most of the following passages can also be found in Peter Pešić (ed.), *Junior Laboratory Manual* (Santa Fe: St. John's College, 1986), 2 vols.
4. Newton, *Opticks*, pp. 374–75.
5. *Ibid.* pp. 370–71.
6. Isaac Newton, *Principia* (Berkeley: University of California Press, 1962), vol. 2, p. 634.
7. Cited by Maxwell in W. D. Niven (ed.), *The Scientific Papers of James Clerk Maxwell* (New York: Dover, 1965), vol. 2, p. 316.
8. See Christiaan Huygens, *Treatise on Light*, in *Great Books of the Western World* (Chicago: Encyclopedia Britannica, 1952), vol. 34, pp. 553–75.
9. Newton, *Opticks*, p. 368.
10. *Ibid.*, p. 370
11. *Ibid.*, p. 349.
12. *Ibid.*, p. 352.
13. Newton, *Principia*, vol. 1, pp. 19 ff.
14. *Ibid.*, vol. 2, p. 634.

15. Newton, *Opticks*, p. 400.
16. I. Kant, *Metaphysical Foundations of Natural Science* (Indianapolis: Hackett, 1985), p. 132. See L. Pearce Williams, *The Origins of Field Theory* (Langham: University Press of America, 1980), pp. 32–43. I have continued this inquiry in a forthcoming essay "The Principle of Identicality and the Foundations of Quantum Theory."
17. Aristotle, *De Anima* 418b 9–10.
18. *Ibid.*, 418b 14–17.
19. *Physics,* II, 194b 9.
20. Newton, *Opticks*, pp. 362–63.
21. See the valuable essay by Thomas K. Simpson, "Maxwell's *Treatise* and the Restoration of the Cosmos," in *The Great Ideas Today*, (Chicago: Encyclopedia Britannica, 1986), p. 226.
22. *Ibid*, p. 227.
23. Faraday, "On the Physical Lines of Magnetic Force," included with his *Experimental Researches in Electricity* in *Great Books of the Western World* (Chicago: Encyclopedia Britannica, 1952), vol. 45, pp. 816–19.
24. Faraday *Experimental Researches in Electricity* (New York: Dover, 1965), vol. 3, pp. 435–36.
25. L. Pearce Williams (ed.), *The Selected Correspondence of Michael Faraday* (Cambridge: Cambridge University Press, 1971), vol. 2, p. 882.
26. See, for instance, J. C. Maxwell, *A Treatise on Electricity and Magnetism* (New York: Dover, 1954), §528.
27. Faraday, *Correspondence*, vol. 2, p. 882.
28. *Ibid.*, vol. 1, p. 134.
29. *Ibid.*, vol. 2, p. 864.
30. Faraday, "Thoughts on Ray Vibrations," in his *Experimental Researches in Chemistry and Physics* (London: Taylor and Francis, 1859), p. 370 (reprinted identically by Culture et Civilisation, Bruxelles, 1967).
31. See his writings on the theory of molecular vortices to be found in Maxwell's *Scientific Papers*, vol. 1, pp. 451–88.
32. Victor Zuckerkandl, *The Sense of Music* (Princeton: Princeton University Press, 1959), p. 37.
33. See, for example, P.A.M. Dirac, *Quantum Mechanics* (New York: Oxford University Press, 1958 [4th edition]), pp. 306–10. I have also addressed this matter in a forthcoming essay, "Virtuality and the Paradox of the Vacuum."
34. See Einstein's "Autobiographical Notes," in P. A. Schilpp (ed.), *Albert Einstein, Philosopher-Scientist* (New York: Harper and Row, 1959), p. 9.