# THE FIELDS OF LIGHT

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Studies in the laboratory occupy an important place in the activity of St. John's College. It is my hope to explore in particular the nature and significance of the study of the field theory of light and of electricity and magnetism which we undertake during the junior year. This taxing and difficult project often raises the question exactly why it is important for us. Sometimes it is argued that we should study laboratory science to "balance" the literary and philosophic work we do; I would question the difference (or even anitpathy) that this presumes between scientific and humane studies. Again, scientific studies are defended by appeal to the need to help St. John's' members be scientifically literate citizens of the Republic who can judge with some insight the claims or the advice of scientific "experts". Also, some praise the utility of scientific knowledge to our graduates as they make their way in the world.

There seems to me to be merit in these claims, but they are not the reason why I myself value the opportunity I have had to participate in the junior lab program. For me the laboratory is an occasion to encounter a kind of beauty which ennobles the spirit. I would submit that our laboratory work is good for the soul, especially the manner of considering original texts and experiments, which is a rare activity we do almost alone in the world. In the particular case of our study of light, I believe it becomes the study of the soul itself as revealed in the radiant vesture of Nature. In so doing the laboratory is shown to be an integral, even central, part of the activity that we cherish. Perhaps the personal ruminations offered this evening might help suggest the manner in which the study of light which we undertake in the junior lab illuminates and is illuminated by our other studies.

My beginning is darkness, in Plato's Cave; it seems crucial that in his logos it is light, the light of the sun, that represents that which is. Indeed, the word eidos so often translated "form" or "idea" comes from the root wid, to see; so an eidos is in some sense a "look", something seen, though constantly and paradoxically this sort of looking is distinguished from the act accomplished with the eyes even as it is spoken of in terms of that more ordinary sort of seeing. At least, Plato suggests there is a sort or turning around (tropos) to behold the sublime and true object of sight, that is, not only the visible forms but what he would call their eidos, or their "look", in a deeper sense. How is such sight possible, with its double meaning of vision in the ordinary sense and of insight? Plato suggests that "this power is in the soul of each and that the instrument? with which each learns--just as an eye is not able to turn toward the light from the dark without the whole body--must be turned around from that which is coming into being together with the whole soul until it is able to endure looking at that which is and the brightest part of that which is. And we affirm that this is the the good, don't we?"[1] So somehow there is a power in the eye as in the soul which prepares the possibility of this sight. Elsewhere he suggests that the eye grasps its object in a most literal fashion, that the eye somehow sends out rays whose encounter with an object constitute the act of vision.[2] This seems to me a deep suggestion, for it portends the active engagement (rather than passivity) of the eye in the act of vision, and, by implication, the sense that vision is not merely a fine metaphor for the inward contemplation of the good, but that there is a deep and necessary connection between what we call ordinary sight and such insight.

Surely, Socrates would have us ask ourselves what we mean by "ordinary" here. I am helped by music. In the liturgical sense, the ordinary chants of the mass are those always sung on every occasion, as opposed to those proper to the given day. The Easter Mass, or indeed any one, is a combination of ordinary and proper parts. So, too, ordinary vision is not something inferior, but, like the Gregorian Kyrie or Credo, as glorious as it is ubiquitous. I do not know whether this Gregorian comparison is compelling, but surely a Socratic questioning would have us examine very closely "ordinary" vision as a necessary part of the intimate connection Socrates offers us between such vision and deeper insight. The connection is of utmost interest even if there is some tension between ordinary sight and insight. One thinks of Oedipus and Gloucester, who says "I stumbled when I saw."

So I return to ordinary sight with the conviction that understanding it is capital unless it were to be understood as merely a disposable part of Plato's analogy in the cave; that is, I submit that ordinary sight is not merely the pretext for Plato's image, but an integral part of understanding what Plato means by "looking at that which is".

Perhaps it is most helpful at this point to speak of another account of ordinary sight that we read; its most eloquent advocate is Lucretius. Rather than the eye somehow sending our beams to explore its object, Lucretius, following his master Epicurus, suggests that the object itself sends out films of atoms which detach themselves from the outer surface of the object and float outwards.[3] Some of them, quite by accident, encounter the eye and hence give rise to the visual image. Others, impinging upon ears and nose, give rise to sounds or smells. As a counterpoint to Plato, this seems very different. The eye here is a passive receptor which somehow converts the impinging atoms into the visible sensation. Thus the basis of vision is said to lie in travelling material substances.

This is evidently a powerful account and is in many ways similar to the one Newton offers much later in his Opticks. However, for Newton the light is not simply atoms from the surface of the body which enter the eye, but rather he speculates that the rays of light are "very small bodies emitted from shining substances".[4] So the light is distinguished from the shining substance that emanates it, and Newton delights in this transmutation. As he says, "The changing of Bodies into Light, and Light into Bodies, is very conformable to the course of Nature, which seems delighted with transmutations... Eggs grow from insensible magnitude, 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?"[5] I am struck by the way Newton grasps at all these organic images of transformation in speaking about what he describes elsewhere as a mathematical principle which underlies the behavior of light rays, themselves composed of inorganic bodies.

A crucial similarity to Lucretius remains: light is "very small Bodies" travelling until they impinge upon the eye, which is a material structure also. Many powerful conclusions flow from this approach. Color, for Newton, is understandable in terms of the different sizes of the light particles; refraction is the effect of the glass of water which speeds these particles up as they move from air into the glass or water. So a comprehensive account is formed that seems to encompass all known optical phenomena. Yet, as Newton admits, this 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. That is, in his Queries, Newton suggests that particles of light will now most readily account for the theorems he proved earlier when speaking of rays of light, such rays being mathematical entities which he had discussed as such without needing to specify the nature of those rays. It seems that, to Newton, there is a difference in the assurance with which he speaks of the rays and their mathematical properties and the diffidence with which he speculates that the rays are indeed 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 Reaction at a distance very much resembles an attractive Force between Bodies".[6] 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. No, mathematically it seems simply to act at a distance, as he puts it, and we should not then "feign the hypothesis" that such action at a distance then implies transmission of the force by passing in some describable way through the space intervening between the two bodies.

So in his public writings Newton felt that simply 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,

> "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."[7]

Indeed, 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 he says, "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."[8] 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[9] that presumed the existence of a universal medium or aether and described light as waves travelling through this medium, much as water waves represent a state of vibration which passes through the medium of water. Huygens imagined the space between bodies packed with small, hard particles of equal size, so that when a body began emitting light at some point, what really happened was that these ether particles would transmit a shove much like a pool table packed with billiard balls would transmit any 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 Phenomena 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."[10]

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 etherial medium pervading space. Thus for Newton, the notion that rays of light are "very small Bodies emitted from shining Substances"[11] is vastly preferable.

But it is important to add immediately that, though he rejected the dense medium he felt was necessary for Huygens' 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."[12] 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 etherial medium is not like Huygens' "which fills all space adequately without leaving any Pores, and by consequence is much denser than Quick-Silver or Gold".[13] Yet the resistance of Newton's ether would be inconsiderable, he argues, because it is so rarefied. Hence one understands that there are void spaces between the ether particles that permit Newton's ether to be more or less rarefied or compressed. Those same void spaces allow his ether to slide around the planets without hindering them, whereas Huygens' 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 of 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 read 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 yet more striking 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 which strike eachother, 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 which somehow accomplish this mediation. Eventually, we must face the question: action at a distance or direct contact?

Huygens' notion of direct contact would seems satisfying except for Newton's objections and the further problems 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 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.[14] 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 are not coincident, 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 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 precise sense of direct contact, because I cannot find the moment of contact even if I picture the bodies as points or composed of points.

I think it must have been difficulties such as these that moved Newton to speak of action at a distance, since no simple of action by contact will do. And it was the inscrutability of action at a distance that made him speak of "the mediation of something else, which is not material...".[15] In a way, this seems a reasonable escape from our dilemma. If action by contact is a naive fallacy, then the mediator cannot be simply material by "something else". At first this leads to the startling conclusion that this natural philosophy which spoke so simply of matter cannot remain complete without invoking a mediation which is not material to render comprehensible the interactions of matter. 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, 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). Turning to

Newton, in a celebrated passage he says, "All these things being considered, 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, were 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."[16] 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 those atoms make them so extraordinarily hard. And these forces are not of themselves material, Newton has already suggested. The atom seems to dissolve into a constellation of forces. Even were the atom utterly dimensionless and point-like, we would have the pregnantly absurd situation of matter, which presumbably 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 <u>at a point</u>. If we cannot say that there is matter at any point, where then is it?

Somehow our problem reflects an ambivalence in Newton's own thought between the material, physical world and the mathematical principles, which speak of forces which are not material but mathematical entities. In this mathematical view mass itself is a 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 which are not material simply. 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 jars against that of "stuff" and matter. It was Kant's great insight at this point to say that what we can <u>know</u> of matter is force, and only force. To attempt to speak of matter <u>in</u> 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 "no possible object of our experience".[17] 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 <u>Natur</u> <u>philosophie</u>. My own feeling is 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.

But let me turn away from Kant and return to Newton's thought that it does make sense to speak of "solid, massy, hard, impenetrable particles".

What is it that makes us so sure that "brute inanimate matter", as Newton calls it, sheer stuff, really <u>must</u> be part of our conception of the world? By doing so 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, sights. But our argument has led us to see the solid mass of matter dissolve into a web of interacting forces. Why do we confine 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.

Nevetheless, even with the greatest enthusiasm for the notion of matter and even primitive particles as Newton had, we have been led to consider this maze of forces as simply 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. Like it or not, we have left matter behind in our considerations. We have yet to consider whether by so doing we have merely constructed a pale shadowy mathematical representation at the cost of the full-bodied experience we pay homage to when we speak of stuff.

This returns us to the heart of our question concerning light. Whether we begin with streams of light particles, as Newton does, or 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. Here is where we must look for the heart of light.

It is here that Aristotle helps us deeply in a way which 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".[18] 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 of fire or something of such kind being present (parousia) in the transparent".[19] 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 an 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 which is light, but rather 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 own.

In the case of light, Aristotle seems to speak, then, 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 deeply 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 at a region replete with substance, not void anywhere. In that respect Aristotle seems much closer to Huygens' picture of a dense medium through which vibrations pass. So Aristotle's view emerges as an immensely suggestive synthesis of Newton's play of forces (which he might understand as a sort of energeia) and Huygen'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 indeed light were wavelike motion propogated through a fluid medium, like water waves, it would necessarily follow that light shoudl 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 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. It was surely after Thomas Young first observed phenomena which indicated that indeed light does not simply travel in straight lines but indeed bends around obstacles just as Newton proposed and as water and sound waves do. This seemed to be the moment of triumph for Huygens' notion of a vibrating medium and of disgrace for the Newtonian picture of light as a particle. Indeed, in the century following Young's first experiments showing the wave nature, 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, I suggest, we see the wonderful reappearance of Aristotle's notion of energeia, its triumphant phoenix-like rebirth after centuries in which Aristotle's physical thought was usually said to be simply wrong, dead, and useless. To me this is an essential example of how the process of thought does not really unfold simply historically, the latter views a product of what preceded them. Although it is not widely appreciated, I would argue that Aristotle grasped an essential facet of the problem of light in a way I only begin to appreciate after reading Newton, Huygens and Maxwell.

But I must return to these fields. The term field in this sense was essentially 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 speaks much about those two incomprehensible and wonderful men, Faraday and Maxwell. Proust once remarked tht every true artist brings a new kind of beauty into the world.[21] And, I would add, in the process of bringing this new kind of beauty to light, a special sort of heroism must be shown. Perhaps Faraday is, for me, the most touching sort of hero in this way. The son of a blacksmith, and himself a bookbinder's apprentice, by dint of reading and a deep desire to explore the mysteries of the world, he became a lab technician assistant at the Royal Institution in London and, over many years, became the great experimenter and thinker. A kindly and lovable man, he became, though formally uneducated, the 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"[22] to boot, quite uneducated mathematically and separated from the great tradition of mathematical physics that Newton inauguratedwith his Principia. Faraday wrote no treatise as Newton and Maxwell did, but rather his wonderful Experimental Researches and his Diary. As Mr. Simpson has so finely said, these works are "not theory, but a vast weaving and unweaving of powers, a process of 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: he 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 to investigate all the powers of nature, and to unveil them as essentially one, in the lecture hall on Albemarle St."[23]

I must say first that 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 fields, 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 has 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 make the force visible, yet 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."[24]

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 says 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."[25]

Faraday seemed happiest with a vision in which his physical lines of force arch through space, without even ether, immaterial 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 carying with them everywhere the same amount of attractive power..."[26] 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.[27] 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..."[28] 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 have a mathematical form and which he calls a field. Those physical, yet immaterial, lines of force Maxwell understands as states of a medium, of an ether that must necessarily be there, and the fields are the states of polarization of that medium.

Though indeed Maxwell describes himself as translating Faraday's ideas into a mathematical form, the differences between the two men are extremely interesting. Faraday himself, writing to the great theorist Ampère, said, "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 fron the incapability I lie under of following it, notwithstanding all my exertions....I fancy the habit I got into of 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."[29] And to Maxwell, Faraday said, "I was at first almost frightened when I saw such mathematicl force made to bear upon the subject, and then wondered to see that the subject stood it so well."[30] There is gentle irony here, as well as real awe concerning 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 serenly confident that posterity would sift the gold from the dross. Yet I cannot escape the note of a wistful Moses who sees the promised land from afar off and recognizes that he will not himself enter into the fullness of it. I suppose Moses' own entry into the promised land was just that act of vision, which perhaps has an integrity and magnitude even apart from settling the promised land, the settlement that Maxwell would begin.

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 "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".[31] It seems to me that this discovery is perhaps 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 excellances in both men that should be savored. Together they saw how the field leaps free of its source and can travel through boundless space. These fields are the recent, vivid incarnation of Aristotle's insight concerning light as the actualization of waiting transparancy.

Maxwell followed Faraday also on a further flight of speculation. If indeed these lines of force flex far from any body and their state of tension is the true seat of the electromagnetic interactions, perhaps the action of electric charge as a sort of fluid or simple material substance should simply be abandoned.

As we speculated earlier, the true actuality of electricity, magnetism, and light lies in the mediating fields; matter and charge seem to dwindle and disappear from sight. At first Maxwell tried to think of "empty space" as filled in imagination, with gears and idle wheels, a whole elaborate mechanical structure that helped guide his understanding as he wrought his four mighty equations.[32] 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. 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 in our attentions. In the remainder of my talk I would like to consider how to understand and assess this extraordinary, paradoxical situation.

First of all, its seems very odd simply to discard matter in favor of the immense explanatory power of the forces and fields. Here I am helped by thinking of music. Victor Zuckerkandl has said that "music is movement of tones in dynamic fields".[33] And indeed in no single note is the music, but rather in the web of interrelationships that can be aptly termed a field. That is, the music is really *between* the notes, in the *metaxu*, as Aristotle might say, the in-between that comes to *energeia*. The music is in the silence. That is as much to say that there is *no* silence in the sense of a void, utterly blank. Such an utter emptiness would essentially negate, even destroy, the possibility of music. The silence that preceeds a piece of music is, indeed, part of it, as one realizes watching the different silent gestures a conductor uses to give the up-beat that preceeds 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 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 physically contradictory with the manifestation of fields.[34] This agrees deeply with Aristotle and gives the sense that the seemingly empty space, the silence, is in truth the heart of activity, of music. It would miss this heart to say that music is E's and G#'s as if they were the stuff of it. Likewise, pointing to objects and stuff as if they were the key to physics misses the heart of it. 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. May I give you one 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 20, and which also became the song "Im Fruehling". 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):


Here the silences form a final revelation of the inner life of the theme. In each silence something immense happens, to the music and to us. We are plunged into the field of force that is the music, made nakedly visible 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". I suppose it is one of the revelations opened to us by great works of visual art, that we begin to see as we watch the common light of day move miraculously across the wall of a room in a painting by Vermeer.[35] I say revelation because we do not know how to see, and Vermeer discloses to us a mode of vision in which a little bit of wall calls out to us like an apparition of heaven.[35] Surely this is not really a trick of pigments and stuffs simply, but is a field of relationships and of mediation. Similiarly, we do not know how to hear, but as we hear Schubert, commonplace notes and chords are cast into miraculous relationships. As we begin to be aware of that, he teaches us to hear; in a way, the relationships call into being their hearer as they disclose a particular mode of hearing. Permit me to extend language a little bit by saying this again, that such a piece of music does not only draw us into a new kind of hearing but raises our faculties so deeply that we might say that it "hears" us. I mean that we are so deeply moved by it that it enters into our soul and does not leave is untouched; so, inventing an active sense of the verb, to hear, the music "hears" us. In that sense, I think that much of what we are about here at St. John's is that these books read us. By saying these odd things, that the great books read us, that the great piece of music hears us, I mean to emphasize that we enter into a field of force where the intense mediation draws hearer and music into a deeply intertwined state. In electricity it is important to speak of positive and negative charge, and we say the spark, the light, somehow leaped between them; yet the spark, the light, was not simply positive or negative, but an energeia, Aristotle might say, which drew them both into a luminous relationship. The manifestation of that energeia is more compelling, to Faraday and Maxwell, then arguing fruitlessly over whether the spark "really" started from the positive or from the negative charge. So, too, we hear the music and it hears us. Our experience really is a field, then.

Perhaps we should ask ourselves whether our spirit, our soul, might best be described or elucidated by this notion of field. Randomly bumping particles and mechanisms don't hold much prospect of touching the sort of beings we are, but speaking of fields is, as I am trying to suggest, perhaps very close to the way we speak of art and love. I am not simply suggesting that there is a vividness and sympathy in the mediated relationships of the electromagnetic field of Maxwell which give us hope of understanding mind and spirit as electromagnetic phenomena. Perhaps there is a reason why this notion of field should seem such an attractive metaphor for light and for music and perhaps for mind and spirit. In my conclusion I will inquire after other grounds that might inform this powerful notion, the field.

Thomas Aquinas in the Summa Theologica, speaks very powerfully of relation as really belonging to God, and says that "relation really existing in God has the being of the divine essence, in no way distinct from it."[36] Earlier we described field as most of all a state of relationship, of mediation, having a kind of integrity that enabled us to speak of this state of relationship in itself. Thomas helps us see that such a state is very similar to the constellation of relations in God which are His essence. It may well be that Thomas's God and the field find common ground in what Aristotle taught us about light as the actualization of the transparent; and active mind as an important principle, which is not matter, but which, like light, makes the colors glow and be actual. I do not pretend to understand what Aristotle is saying here, but I draw from it a notion that some immortal, perhaps even divine, aspect of of our mind is like light. Thomas's light is not material, but sounds very much like a field as it weaves that web of mediated awareness which we recognize as color. Aristotle, Aquinas, and Maxwell seem to be standing close together, on common ground that can be approached as mind, or God, or field.

Light viewed as a field does seem indeed to be very like a divine being, a nexus of relationships like God's. We are helped by the field to understand the Gospel of John when it speaks of God as light; it is more that a superficially appealing comparison if indeed light shows further something of the divine essence, the first-born among creatures, as Genesis says. Indeed, many great visionaries have spoken in this vein; let us hear Milton:

> Hail, holy Light, offspring of Heav'n first-born,
> Or of th'Eternal Coeternal beam
> May I express thee unblamed, since God is Light,
> And never but in unapproached Light
> Dwelt from Eternity, dwelt then in Thee,
> Bright effluence of bright essence increate.[37]

We are left with the deep question of "increate", that is, uncreated Light, which is truly God, and to be distinguished from created, ordinary, light. Are we to think that both are light, but one simply lacks a source such as have all the lights we know? Or is the nature of the uncreated light quite different, not to be joined under the species of field, which describes ordinary light? I am tempted to see both adhering to the notion of field, of mediation and interrelation, though I am left with the question of the purely uncreated light. I must stop in respectful silence before the uncreated light of which the great mystics speak. Doubtless I would go astray in this playful suggestion of the field inhering in both Divine and created light. Yet perhaps I can be forgiven for examining it further.

The notion that the uncreated Light is utterly different that the created, physical light raises the deepest questions about the world we see and some divine, perfect world beyond or behind it. It is the question of whether the divine, increate can become manifest in the physical. It is, in a way, the question of the Incarnation. It remains, to our thinkers, a question. It is interesting that Newton who at least publicly advocated unmediated action at a distance, privately could not accept the doctrines of Christ as a divine Incarnation and of the Trinity.[38] The mediator that he seeks in understanding forces is not material; the parallelism between the world of appearances and that of the world of mathematical principles is thus deeply mysterious. I think a kind of tact, of respect before this mystery led Newton to be silent before it.

Maxwell and Faraday also responded, though differently. For Maxwell there is a universal substance, ether, which fills all Newton's absolute space. This ether is physical, is a stuff, he tells us, and its states of vibrations are the fields of light. The divine mathematical principles are thus immanent and incarnate in states of vibration of matter.

Faraday answered differently. For him, an ether seems really inappropriate, but the vibrations are the heart of it. What we call the world and matter are the outward appearances of these lines of force, which manifest a wonderful and divine providence. Faraday will not hallow a mathematical realm apart from the realm of our experiences; his reluctance to mathematics is deep. This world is an intelligible fabric, but not of brute matter. By refusing to admit that the world is matter, even etherial matter, informed by a separate mathematical realm, Faraday might be speaking of the deep and immanent presence of divine goodness in the world. I do not think it right to say that, for Faraday, the world was God. Faraday always insisted publicly on a profound difference between religious belief and "ordinary belief," as he termed it.[39] He was deeply reluctant to speak of matters that were only between him and his God. So my speculations here are probably quite inappropriate.

Yet I do feel that the question raised here is not peculiarly a theological or Christian question. Every thinker concerned with the natural world who explicates that world in terms of underlying principles which are perfect or sure is in some way facing the question of yoking together the two worlds, one of sense and experiment, the other intelligible and orderly. When Plato tells us that the Forms are those things which most of all are, he is addressing the same question in his way, for the Cave remains, now to be re-entered in the light of the things which are. The notion of field also means to help us draw together an intelligible order from the complexity of our experience. It joins Aristotle in emphasizing the importance of the gap across which light moves.

That transparency is deeply like the soul. It is the silence replete with the fullness of music. In music one speaks of intervals or distances between notes which are not really located in space like objects. Yet the _felt_ sense of distance or stretch, of skip or step, is essential to the experience of music. The musical intervals and spaces are within the soul; perhaps, as Plato suggest, the soul is indeed made of music.[40] The fields of light also may be most deeply within the soul. As Kant might suggest, as we see the world in terms of fields, we gaze within. The hearing of music revealing interval, the seeing of light revealing space and time, are the soul beholding itself even as it looks outward.

Music and light are the soul experiencing what thought names space and time. The best work for what the soul experiences is love; light, space, time, music are modes in which the soul knows love: love felt, love lost, love found again. So, like Odysseus, like Faraday, men of many ways, through long journeying, we at last return home again.

# NOTES

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6 Ibid., pp. 370-371.
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11 Ibid., p. 370.
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27 See, for instance, Maxwell's Treatise [528] (included in Manual p. 103.
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35 Proust, op. cit., vol III. p. 187.
36 Summa Theologica I, Q. 28, art. 2.
37 Milton, Paradise Lost III, ll. 1 - 6.
38 See F. Manuel, The Religion of Isaac Newton (New York: Oxford University Press, 1974).
39 See L. Pearce Williams, Michael Faraday, p. 103.
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