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FARADAY'S THOUGHT ON ELECTROMAGNETISM

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This is part of the first chapter of a study of a neglected great book, James Clerk Maxwell's Treatise on Electricity and Magnetism. The Treatise appeared on the original reading list of the new program, but apparently was taken off just in time for my senior year in 1950; I never read it as a student. Apparently it was a hard book to incorporate in the program. The problem of my study is, really, how to read a book of analytic mathematical physics. Interestingly, it develops that the book and the problem are well matched, since Maxwell, writing one of the last great works of natural philsophy, is wrestling with the question, how to write a book of analytic mathematical physics in such a way that it can be read with understanding. Maxwell wages a relentless struggle with the symbols throughout the book, trying all the while to develop a rehetoric of mathematical physics which will make the equations intelligible. The present chapter is not about the Treatise, however, but about another great book (also a dropout from the reading list), Faraday's Experimental Researches in Electricity. The reason why the study starts with the wrong book is given in the first pages. --T.K.S.

In an extraordinary way, Maxwell's Treatise on Electricity and Magnetism presupposes that the reader is already familiar with another book, Faraday's Experimental Researches in Electricity. One can indeed master the Treatise without having read Faraday, but such an approach cannot lead to the understanding which Maxwell deeply desires to share with the reader. Many works refer repeatedly to a single principal source, but there must be few which command their readers as Maxwell does in a footnote to Chapter III of Part IV: "Read Faraday's Experimental Researches, Series i and ii".[1] As I have asserted earlier, Maxwell has designed his Treatise as a faithful translation of Faraday's Researches, and throughout, Faraday is the mainspring of the work and the guide to its development. But Maxwell not only draws upon Faraday as his source; in a curious way he makes this source the object of his work as well. We are directed back to Faraday, to read with renewed appreciation and understanding:

> If by anything I have here written I may assist any student in understanding Faraday's modes of thought and expression, I shall regard it as the accomplishment of one of my principal aims--to communicate to others the same delight which I have found myself in reading Faraday's Researches.[2]

It is therefore essential that the present study of Maxwell's Treatise should begin with some consideration of Faraday's Experimental Researches.

No summary can convey either the content or the character of Faraday's writing. As perhaps the ultimate example of their genre, the literature of scientific inquiry organized episodically in linked series, they are a texture of speculation and intelligent experiment so interwoven that it is virtually impossible to isolate significant sections from their context of detail. The point of the work is in effect this very mass of theme and variation. What I hope to do in this chapter, rather, is first to discuss the nature of science as Faraday conceives and practices it, and then to identify certain principal insights which Faraday tended to bring to bear on electromagnetism in his later work. These last constitute the primary material with which Maxwell works in Part IV of the Treatise. Since it appears to me that these insights, however powerful, by no means constitute a theory, I have titled the present chapter simply "Faraday's Thought on Electromagnetism," and not "Faraday's Theory". As we shall see, one way of looking at the "translation" of Faraday's ideas which Maxwell accomplishes is exactly as the transformation from the mode of empirical inquiry in which the Researches are cast, to that of theory, demonstrated in a systematic treatise.

Faraday developed two concepts which became increasingly significant in his thought about magnetic and electromagnetic effects. One was of course his concept of "lines of force". He was impressed by this notion early when he spoke of the lines merely as representations, and called them, as others did, the "magnetic curves." Toward the end of his work, they bore nearly the whole burden of his thought on these topics, and he speculated increasingly about their possible "physical existence." The other fundamental concept was that of the electrotonic state. This is now less familiar to students of science, but for Faraday it was both significant and deeply troubling, and he returned to it, as Maxwell points out, again and again from its first introduction in connection with the induction experiments of Series I in 1831, to the end. Essentially, Faraday was convinced that the surge of current which he observed in the secondary circuit in electromagnetic induction could not occur unless the secondary conductor had been initially in a state of electric tension, which was relaxed when the primary circuit was broken. The term "electrotonic" was manufactured to express this electric tension. As we shall see, Maxwell's translation of Faraday's thought on electromagnetism turns about these two notions, the "lines of force" and the "electrotonic state."

For Maxwell, then, these will become fundamental concepts in a connected theory. But what

[1] James Clerk Maxwell, A Treatise on Electricity and Magnetism (3rd ed., 2 vols.; Oxford: 1892), 2, p. 178. (This is the edition currently available in a Dover reprint.) Maxwell, Treatise, 1, p. xi.

sort of use does Faraday himself make of them? I think it becomes clear on a reading of the Experimental Researches that Faraday does not use them as elements of a scientific theory in any formal sense. Even if we were not to ask for a connected or complete theory, doubt arises whether concepts in Faraday's hands even tend toward inclusion in a provisional theoretical structure. The question, indeed, becomes more fundamental: does science, for Faraday, grow toward a theoretical shape, or does it develop toward something else altogether, not theory, but an account of a different kind?

We might attempt to answer the question by putting Faraday's account to certain tests, asking it to do the kinds of things theories are expected to do: to solve "problems," to "predict" phenomena on the basis of certain given conditions, or to yield general "theories" through logical argument from assumed premises. But these functions, though they are surely among the proper tasks of an effective scientific theory, are precisely those which Faraday does not undertake.

Faraday was almost totally uneducated in mathematics. It is difficult to grasp the significance of this fact for science. However brilliantly he succeeded in self-education in other areas, he apparently never felt it necessary to acquire the mathematics he had missed. The result is that he does not have before him with any vividness that universal paradigm of a reasoned deductive system, toward which virtually all competent physics over the ages has tried to shape itself. In particular, Faraday apparently never studied Euclid; he has no working notion of a system of axioms and postulates, or of reasoning leading with logical rigor to universal theorems.

There is at least the possibility that this innocence of mathematics represents not merely accidental ignorance, but a deliberate rejection. We are blessed with the record of a remarkable exchange of correspondence between Faraday and André-Marie Ampère, the French philosopher and mathematical physicist, whose work on electrodynamics Duhem once called "a theory which dispenses with the Frenchman's need to envy the Englishman's pride in the glory of Newton." Here Faraday confronts his opposite, a brilliant mathematical theorist, and in the course of the correspondence Faraday finds occasion to describe his view of his own role. We shall return to this in greater detail below, but note this reaction of Faraday's when confronted with a mathematical argument of Ampère's:

> I regret that my deficiency in mathematical knowledge makes me dull in comprehending these subjects. I am naturally skeptical in the matter of theories and therefore you must not be angry with me for not admitting the one you have advanced immediately...[3]

This skepticism of theory, I believe, turns him away from mathematics almost on principle. He tends to regard mathematicians as operating on a height, while his own work, as experimentalist, is close to nature, and to fact; it would be a mistake, I believe, to overlook the element of pride which mixes with humility in his descriptions of his more modest work. In a moment of triumph following upon the discovery of electromagnetic induction and the explanation it afforded of the Arago disk phenomenon, he wrote to his friend Richard Phillips:

> It is quite comfortable to me to find that experiment need not quail before mathematics, but is quite competent to rival it in discovery; and I am amazed to find that what the high mathematicians have announced as the essential condition to the rotation...has so little foundation....[4]

There is a suggestion of a moral note in Faraday's rejection of theory, as will become clearer when we look at his characterizations of the true form which science should take. In relation to mathematics, this passage from the work which Faraday early adopted as his pocket guide, Isaac Watts' Improvement of the Mind, may be significant:

> But a penetration into the abstruse difficulties and depths of modern algebra and fluxions, the various methods of quadratures...and twenty other things that some modern mathematicians deal in, are not worth the labour of those who design either of the three learned professions.. This is the sentence of a considerable man.. who was a very good proficient writer on these subject; he affirms, that they are but barren and airy studies for a man entirely to live upon...He adds further, concerning the launching into the depth of these studies, that they are apt to beget a secret and refined pride, an over-bearing vanity, the most opposite temper to the true spirit of the gospel. This tempts them to presume on a kind of omniscience in respect to their fellow-creatures, who have not risen to their elevation...[5]

Faraday remained, in a phrase he used without, I think, any hint of apology, an "unmathematical philosopher."

Maxwell grew up solving problems; as a child, he carried them with him for spare moments, calling them his "probs"; as a man, he filled his Treatise with them. By contrast, for all we know, no teacher may ever have set Faraday a problem, ever assigned him certain "givens" and required him to find the corresponding "unknowns." Naturally enough, then, he does not think of his electromagnetic notions as serving this purpose, and a reader cannot make much of the Experimental Researches if he comes to them with this criterion in mind. It is not only that Faraday cannot perform the operations of algebra or geometry, that he can make only a first approximation to a quantitative argument of any complexity. It is not only that he uses spatial images and models where others would work with number and symbol. It is not that he uses brief arguments where others would construct theorems. To a degree, these may all be true of Faraday, but as I express them they suggest defects; in Faraday's case, they must be construed as aspects of his special strength. His steps are not weak and faltering, his works are not those of a man who hesitantly

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3 Faraday to Ampère, Sept. 3, 1822. L. de Launay, Correspondence du Grand Ampere (3 vols; Paris: Gauthier-Villiars, 1936-1943), 3, p. 911.

4 Bence Jones, The Life and Letters of Faraday (2 vols; Philadelphia: 1870), 2, p. 10.

5 Isaac Watts, The Improvement of the Mind (Washington, D. C.: 1813), p. 213.

approaches a language he has not properly learned. Faraday (for all the humility which has been attributed to him) steps forth proudly, and while he is generally cautious and of course always modest in his public claims, he speaks with a voice as confident and firm as that of any scientist who knows the strengths of his own method. He is speaking a different language from that of the theoretical scientist. He is not stepping hesitantly toward a mathematical physics; he is marching confidently along a different road. He has indeed no notion of theory as a goal of science.

In retrospect, this is a fantastic situation. In the land of Newton, at a time when mathematical physics was again flourishing, some of the most creative scientific work of the century in a new and more difficult area of physics was done over a long period of years by a man who had no notion of the Principia and did not share either Newton's methods or his goals. For Faraday, Newton's classic triumph was quite meaningless, the triumph which had polarized the intellectual life of Europe for a century.

How can the historian of science understand the success of such a deep and total disruption of any reasonable continuity in the scientific enterprise? Perhaps the ultimate challenge for the present study is to lay the groundwork for finding the significance of the Faraday-Maxwell episode in the development of mathematical physics. Physics seems indeed to have profited immensely from this instance of amnesia in its work, but it is well to keep in mind that the fact that this one course was followed does not mean that it was in principle a necessary "state" of development, or that it was ultimately for the "best." There is a sense in which the serious historian must always weigh alternative histories. On the Continent there were of course a number of highly competent scientists at work on the topics which concerned Faraday, both mathematicians and experimentalists, and I think one may reasonably suppose that most of Faraday's discoveries would before long have been made by others whose thought was in the tradition stemming from Newton. The great Newtonian counterpart of Faraday was Ampere, but there were many others, Weber, the Neumanns (father and son), Kirchoff, Lorenz, Helmholtz, Boltzmann, Hertz. There were at once capable mathematicians and skillful searchers; had electromagnetic theory developed in the hands of such workers without the peculiar turn of thought given it by Faraday and Maxwell, it is quite conceivable that physics might have passed into the modern era, more or less on schedule, as a more purely mathematical discipline, and without the digression marked by the "field" concept. Accordingly to a number of critics, the field concept was never systematically necessary, and has been the source of much confusion, beginning with the Treatise itself.[6] Faraday's unmathematical physics, therefore, developed and interpreted as it was by Maxwell, may have diverted science from a more rational course of development which would have made little or no use of the concept of the "field," but would have left none of the phenomena unaccounted for.

What then is Faraday's concept of science? It is evident that he is not merely an experimentalist, cleverly providing data for theoreticians to work up into theories. On the contrary, Faraday had one of the most fertile and insistent of speculative minds; in a certain sense, he was constantly producing new hypotheses and his mind was constantly reasoning from them. The result of this, reported in the thousands of paragraphs of the Experimental Researches and the still more numerous paragraphs of the Diary, is 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. Faraday, as Tyndall proclaimed and all the world agreed, 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 is to investigate all the powers of nature, and to unveil them as essentially one, in the lecture hall on Albermarle Street. If Faraday did not learn this from Homer, he was moved to it by Dr. Watts:

> Let the hope of new discoveries, as well as the satisfaction and pleasure of known truths, animate your daily industry. Do not think learning in general is arrived at its perfection, or that the knowledge of any particular subject in any science cannot be improved, merely because it has lain five hundred or a thousand years without improvement. The present age, by the blessing of God on the ingenuity and diligence of men, has brought to light such truths in natural philosophy, and such discoveries in the heavens and the earth, as seemed to be beyond the reach of man...
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> . . . . . .
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> Do not hover always on the surface of things, nor take up suddenly with mere appearances; but penetrate into the depth of matters...[7]

Here is Faraday's own characterization of his hope for his chosen science of electricity, in a passage which opens the famous Series XI on induction:

> The science of electricity is in that state in which every part of it requires experimental investigation; not merely for the discovery of new effects, but what is just now of far more importance, the development of the means by

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6 The classic cruticism of Maxwell's theory is Pierre Duhem, Les Theories Electriques de J. Clerk Maxwell (Paris: Hermann, 1902). Outstanding among the more recent critics is O'Rahilly, who recommends a direct particle/particle interaction equation in the tradition of Wilhelm Weber. Alfred O'Rahilly, Electromagnetics: a Discussion of Fundamentals (1935), reprinted as Electromagnetic Fundamentals (2 vols.; New York: Dover Publications, 1965), especially pp. 645 ff. See also J. A. Wheeler and R. P. Feynman, "Classical Electrodynamics in Terms of Direct Interparticle Action," Reviews of Modern Physics, 21 (1949) pp. 425 ff., and articles by Parry Moon and D. E. Spencer, among them "A New Electrodynamics," Journal of the Franklin Institute, 257 (1954) pp. 369 ff., and "Electromagnetism without Magnetism," Amer. J. of Physics, 22 (1954), pp. 120 ff.

7 Watts, Improvement of the Mind. p. 24.

> which the old effects are produced, and the consequent more accurate determination of the first principles of action of the most extraordinary and universal power in nature:--and to those philosophers who pursue the inquiry zealously yet cautiously, combining experiment with analogy, suspicious of their preconceived notions, paying more respect to a fact than a theory, not too hasty to generalize, and above all things, willing at every step to cross-examine their own opinions, both by reasoning and experiment, no branch of knowledge can afford so fine and ready a field for discovery as this. Such is most abundantly shown to be the case by the progress which electricity has made in the last thirty years: Chemistry and Magnetism have successively acknowledged its overruling influence; and it is probable that every effect depending upon the powers of inorganic matter, and perhaps most of those related to vegetable and animal life, will ultimately be found subordinate to it. (XR i/360) [8]

I think I do not need to apologize for including this lengthy quotation entire; in one paragraph Faraday has given both his vision of nature, and the method of science proportioned to it. He describes an impasse in the science of electricity--one in which phenomena are known in plenty, but first principles are lacking. To another man, this would look like a situation which called for a theory; but for Faraday, this is precisely the situation which calls for "experimental investigation"; it is a "fine and ready...field for discovery." What is to be sought? Not axioms or laws, but the principles of action of a power--the most universal in nature, which moves all of the inorganic world and perhaps for the most part the plants and animals as well. This is not something to be resolved with paper and pencil, but by facts: we see that for Faraday, the causes, the "first principles," are not laws but themselves facts, to be unveiled to observation in the laboratory. We should remember that it was given to Odysseus to talk with Athena, face to face.[9]

This is not theoretical physics; as has been suggested, it is essentially chemistry, not in the modern sense of Lavoisier, but as a science of powers, in the tradition of von Helmont and Stahl.[10] We might best understand Faraday as the disciple of Davy, and the Researches as the evolution of a coherent chemistry of electromagnetism. The translation of Faraday which Maxwell is to accomplish in the Treatise must be, among other things, the transformation of this chemistry into the form of a mathematical theory worthy of admission to the halls of Trinity. In this, it must be like the historic transformation of Greek thought from the mode of Homer to that of Euclid.

The Experimental Researches are dense with questions--Faraday's method is that of unremitting inquiry. The very notion of a "series" of researches is, in a sense, that of a chain of linked questions and answers. Before we bring our own questions to bear on Faraday's work, let us listen briefly to the questions Faraday asks of himself.

The underlying question for Faraday is always the same: what really exists in nature? The practical form which this takes is that of the test: what will happen if I do this? Can I produce the phenomenon, the visible or tangible evidence, which will be the sure symptom of the existence of this or that suspected power or state? Think, for example, of the discovery of the diamagnetic force. (XR, Series 19&20). Faraday had first sought to reveal the state of strain in a dielectric, to which the curved lines of electric action were already a clue; using polarized light, he hoped to make manifest the existence of the hypothesized lines of action of contiguous particles. This failing, he asked the analogous question for the curved lines of action of the magnetic force: do lines of strain really exist in a diamagnetic medium? When this succeeded, and the plane of polarized light was rotated on passage through his "heavy glass" in a strong magnetic field, he announced that he had:

> ...at last succeeded in magnetizing and electrifying a ray of light, and in illuminating a magnetic line of force. (XR iii/2)

By this, he says in a note, he

> ...intended to express that the line of magnetic force was illuminated as the earth is illuminated by the sun, or the spider's web illuminated by the astronomer's lamp. Employing a ray of light, we can tell by the eye, the direction of the magnetic lines through a body... (XR iii/2)

This I believe is a paradigm of Faraday's concept of science: to make manifest to the eye what is suspected to exist in nature. In one of his last writings about the magnetic lines of force, he carefully drew a distinction between the limited powers of mathematical physics as a mode of representing the forces of nature, and his own search for "the one true physical signification" of the phenomena:

> Indeed, what we really want is not a variety of different methods of representing the forces, but the one true physical signification of that which is rendered apparent to us by the phaenomena, and the laws governing them... supposing that... mathematical considerations cannot at present decide which of the views of magnetism is either above or inferior to its co-rivals; it surely becomes necessary that physical reasoning should be brought to bear upon the subject as largely as possible. For if there be such physical lines of magnetic force as correspond (in having a real existence) to the rays of light, it does not seem so very impossible for experiment to touch them; and it must be very important to obtain an answer to the inquiry

[8] The notation (XR i/360) refers to Faraday's Experimental Researches in Electricity, volume i, p. 360, of the original edition, which is reproduced with the same pagination in the current Dover reprint.

[9] It is impossible not to point out the striking appropriateness of the epithet which Homer regularly assigns to Odysseus: in his laboratory, Faraday is indeed the man "of many devices,"

[10] "In a very real sense, all his discoveries were chemical if chemistry be defined (as it was by Faraday) as the science of the powers of matter." L. P. Williams, in Lancelot Whyte, ed., Roger Joseph Boscovich (London: Allen & Unwin, 1961), p. 163.

> respecting their existence, especially as the answer is likely enough to be in the affirmative. (XR iii/531)

An hypothesis or a theory is nothing more than an unresolved suspicion; a part, as Tyndall suggested, of the scaffolding, not of the edifice of science itself, which moves on to deal with existences.

He then demands of himself, what it is which has been revealed by the new phenomena. It is a condition of tension, and therefore of force, because it relaxes as soon as the magnetic induction is removed, but is it the same as the magnetic force, or different? He tests, by determining whether the diamagnetic body responds to a magnet; not observing any motion, he concludes that:

> ... [T] he molecular condition of these bodies, when in the state described, must be specifically distinct from that of magnetized iron, or other such matter, and must be a new magnetic condition; ...the force which the matter in this state possesses and its mode of action, must be to us a new magnetic force or mode of action of matter. (XR iii/21)

In other words, having made a force manifest, Faraday proceeds to identify it, by asking whether it is the same as, or specifically different from, previously known forces.

The same line of inquiry, of course, in time revealed that indeed the diamagnetic material does move under the action of a magnet, but moves in a way specifically distinct from the motion of a magnetic material. The existence of the diamagnetic force, first revealed only optically, is now revealed by a second token, a specific type of motion. This motion is summarized in a law:

> All the phaenomena resolve themselves into this, that a portion of such matter, when under magnetic action, tends to move from stronger to weaker places or points of force. (XR iii/69)

There follows a brilliant experimental inquiry as to the universality of the new effect, concluding with the generalization:

> All matter appears to be subject to the magnetic force as universally as it is to the gravitating, the electric and the chemical or cohesive forces; for that which is not affected in the manner of ordinary magnetic action, is affected in the manner I have now described... (XR iii/70)

To reveal, to identify, and to generalize--the greatest part of the stream of Faraday's working questions serves these three ends. He frequently reasons by analogy, but for Faraday an analogy functions most often as a tentative identity, drawing him on (as in the case of the diamagnetic and magneto-optic forces) to decide whether the two analogous powers are finally the same or different.

Admittedly, Faraday is never content to rest with an unexplained phenomenon, and he moves on from a law such as that of diamagnetic action above, to ask why the action occurs. Again, this might seem to be the step into theory, which I have denied Faraday takes. Indeed, he begins a paragraph shortly after with the words, "Theoretically, an explanation of the diamagnetic bodies...might be offered..., " and proposes an account of diamagnetism in terms of induced polarity, a theory which was as we shall see beautifully successful in the hands of Weber, though Faraday himself soon disowned it. But a theory for Faraday is merely a makeshift explanation, a temporary and unsatisfactory stage of science, which is dispelled as the science progresses. The explanation of diamagnetism which proved more fruitful in Faraday's hands, and which accounted as well for magnetism and magnecrystallic action (the pointing of crystals in the magnetic field), is a good case in point. This is the theory of the conduction of lines of force:

> I cannot resist throwing forth another view of these phaenomena which may possible be the true one. The lines of magnetic force may perhaps be assumed as in some degree resembling the rays of light, heat, & c.; and may find difficulty in passing through bodies, and so be affected by them, as light is affected....the position which the crystal takes...may be the position of no, or of least resistance; and therefore the position of rest and stable equilibrium. (XR iii/122-23)

I submit that the decisive words in this paragraph, for Faraday, are these: "Which may possibly be the true one." Even if this explanation accounted for all the known phenomena, I do not believe Faraday would have rested for a moment until he had found out the lines of force, which here take on a new importance, and given tangible and visible evidence of their presumed passage through bodies. Only thus would the "truth" of the view be exhibited to his satisfaction.

His renewed efforts to reveal the "physical lines" of force are well known. They culminate in papers of 1852 and 1855 (XR iii/437, 528). Here the concern is openly for the real ("physical") existence of the lines, and these papers are therefore "speculative" in a way in which the disciplined researches were not; but I think it is apparent that the whole thrust of the Experimental Researches has been toward this end: to discover the powers of nature, to find out their true characters, and, finally, to produce the guarantees of their "physical" existence. In an apology for speculation, which prefaces the 1852 paper but which really speaks for the role speculation has played throughout the Researches, Faraday says:

> It is not to be supposed for a moment that speculations of this kind are useless, or necessarily hurtful, in natural philosophy. They should ever be held as doubtful, and liable to error and to change; but they are wonderful aids in the hands of the experimentalist and mathematician. For not only are they useful in rendering the vague idea more clear for the time, giving it something like a definite shape, that it may be submitted to experiment and calculation; but they lead on, by deduction and correction, to the discovery of new phenomena, and so cause an increase and advance of real physical truth, which, unlike the hypothesis that led to it, becomes fundamental knowledge not subject to change. (XR iii/408; italics mine)

Speculation is a thread which "leads on" toward the goal of science; the path is through "discovery of new phenomena, " and the terminus is not a completed

theory, but "real physical truth." What then is "fundamental knowledge not subject to change"? As immune to change, it must be manifest in the phenomena; as fundamental, it must consist in those select phenomena which directly reveal the primary, universal powers. Such would be phenomena which made manifest the "physical lines" of magnetic force. In his late, unpublished researches on "Time in Magnetism" Faraday was hard at the effort to capture such primary evidence. [11]

In a recent biography of Faraday, L. Pearce Williams makes a striking observation about the law known as "Faraday's," relating the current induced in a circuit to the change of flux through it. Faraday certainly states the law:

> They also prove, generally, that the quantity of electricity thrown into a current is directly as the amount of curves intersected. (XR iii/346)

Williams points out, however, that in its context in a search for sure evidence of the lines of force, this law "was not directed at electricity at all":

> Faraday was trying to prove that there was a certain specific amount of 'power' associated with every magnet; the induced currents merely detected this power. [12]

Williams adds that Faraday was interested in the induced electricity in Series I, though in the passages cited there Faraday was not stating the quantitative "law". I think this distinction is valid, and significant for an understanding of Faraday's purposes. Whereas the world has taken from Faraday a quantitative law relating motion in a magnetic field to induced current, Faraday himself had his eye on the problem of detecting the "sphondyloid of power" about a magnet; he was seeking out an entity in nature, and using the moving wire with its law of action merely as a highly prized instrument in the search.

This is the physics of the explorer, the discoverer. Throughout the Researches Faraday sought what he called "contiguity" in nature; understandably, he seeks the same contiguity in the account of nature. A work of science should record a completed exploration, a detailed mapping, without gaps, of contiguous substances and powers. Maxwell, I believe, sees this about Faraday, so that it is not merely Faraday's clarity of view and inventiveness which attract Maxwell, but an image of the form physics might take, a physics of contiguity. In the transformation which Maxwell made of Faraday's thought, I believe his objective was not only to find a mathematical expression appropriate to Faraday's electromagnetic concepts, but to bring into analytic form Faraday's insight about the nature of physics itself as a connected system. This calls for a new kind of mathematical physics, field physics.

I mentioned earlier that two concepts are particularly important in Faraday's thinking about electromagnetism, namely the "lines of force" and the "electrotonic state." Thus far, the discussion of Faraday's inquiry into diamagnetism has emphasized only the former, but curiously it was the "electrotonic state" which seemed to Faraday himself the more fundamental idea, and it is this latter which Maxwell takes as the key in his translation of Faraday. For anyone who holds as I do that Faraday did not work with theories, the electrotonic state presents a special problem, since it is a concept which he never abandoned, and yet was never able to support empirically. He held it with tenacity, as we shall see, even though it remained a pure specualtion.

Without attempting to trace the history of this elusive notion through the Experimental Researches, I should like to try to indicate its role in Faraday's thought. In Series I, it appears in effect as the vehicle for Faraday's perplexity at the unexpected finding that an electric current is induced only by variation of the current in a primary circuit, or by motion of a permanent magnet. Like Fresnel, Faraday had expected a magnet to produce an electric effect in a conductor, and even after he had discovered the pulse of current on make or break of the primary circuit, he continued to look for the anticipated effect during steady flow of the primary current. Taking the inductive pulse as evidence of a change of this supposed state, he names it "after advising with several learned friends" the electro-tonic state signifying that it is a tension in the direction of current flow in the conductor, and Series I is conceived more as the announcement of the discovery of a new state of matter, than as the discovery of the phenomenon of induced currents:

> Whilst the wire is subject to either volta-electric or magneto-electric induction, it appears to be in a peculiar state....This electrical condition of matter has not hitherto been recognized, but it probably exerts a very important influence in many if not most of the phenomena produced by currents of electricity. (XR i/16)

He has to confess, however, that he had found no evidence for the existence of the newly named and announced state whatever:

> This peculiar condition shows no known electrical effects whilst it continues; nor have I yet been able to discover any peculiar powers exerted, or properties possessed, by matter whilst retained in this state. (XR i/16-17)

The Experimental Researches thus open with a somewhat embarrassing blunder--for he never was able to find any evidence of the "state" whatever, and in Series 2 he formally withdrew the claim that it exists, though at the same time he reasserted his own conviction that it must:

> Thus the reasons.....have disappeared; and though it still seems to me unlikely that a wire at rest in the neighborhood of another carrying a powerful electric current is entirely indifferent to it, yet I am not aware of any distinct facts which authorize the conclusion that it is in a particular state. (XR i/69)

Before making this reluctant retraction, he had made great efforts to exhibit the existence of some such static state in conductors in a magnetic field: that is,

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[11] Faraday's Diary, ed Thomas Martin (7 vols.; London: G Bell & Sons, 1932-1936), 6, pp. 434-444; 7, pp. 255-333. See T. K. Simpson, Isis, 57 (1966) pp. 423-425.

[12] L. Pearce Williams, Michael Faraday (New York; Basic Books, 1965), p. 463, n. 51.

the efforts to produce an effect in a conductor due to the mere presence of a strong magnetic field did not stop with the discovery of electromagnetic induction, but were if anything accelerated by it. The electrotonic state was the surrogate for the effect which had for years been expected, and which he still felt must exist. The experiments which he performed then, on copper bars and leaves in a magnetic field, were the equivalent of a search for diamagnetism or diamagnetic polarity, and the actual discovery of diamagnetism seven years later, which we have discussed above, was the outcome of essentially the same search for a state of tension due to a steady magnetic field. In effect, the persistent search for the electrotonic state yielded the diamagnetic state.

Faraday himself speaks eloquently of his unremitting dedication to the search for this missing "state"; three years after the retraction, he writes:

> Notwithstanding that the effects appear only at the making and breaking of contact, (the current remaining unaffected, seemingly, in the interval) I cannot resist the impression that there is some connected and correspondent effect produced by this lateral action of the elements of the electric stream [that is, the magnetic action of the current] during the time of its continuance...there appears to be a link in the chain of effects, a wheel in the physical mechanism of the action, as yet unrecognized. If we endeavor to consider electricity and magnetism as the results of two forces of a physical agent, or a peculiar condition of matter, exerted in determinate directions perpendicular to each other...(XR i/342)

He is seeking in the electrotonic state a "physical agent" of which electricity and magnetism are merely two manifestations. In 1852, some thirty years after Series I, he reasserts his faith, now linking the search with that for the physical lines of magnetic force:

> Again and again the idea of an electro-tonic state...has been forced on my mind; such a state would coincide and become identified with that which would then constitute the physical lines of magnetic force. Another consideration tneds in the same direction. I formerly remarked that the magnetic equivalent to static electricity was not known...(XR iii/ 420-421)

He then sketches what amounts to a completed scheme of nature, in which he takes the magnetic line as dynamic by analogy to electric currents, and then inserts the electrotonic state as a static state of magnetism, a magnetic tension analogous to the electrostatic tension which he has asserted precedes all conduction.

The conviction expressed in Series I is reiterated in the last pages of the Experimental Researches; speaking of the wire which experiences a current when it is moved in a magnetic field, he demands:

> Now, how is it possible to conceive that the copper or mercury could have this power in the moving state, if it had no relation at all to the magnetic force in the fixed state?...The mere addition of motion could do nothing, unless there were a prior static dependence of the magnet and the metal upon each other...(XR iii/551)

Even the complex, never-completed experiment on "Time in Magnetism" with which the Diary closes is a search, strictly speaking, for the electrotonic state; he writes to Maxwell in 1857:

> I hope this summer to make some experiments on the time of the magnetic action, or rather on the time required for the assumption of the electrotonic state.... [13]

It would hardly be going too far to say that the Experimental Researches begin, and the Diary ends, with abortive efforts to find the one thing Faraday most wanted to discover, yet for which he was never able to adduce a single definite fact. The momentum of this search carries over, however, into Maxwell's reformulation of Faraday's views, where, as we shall see, the electrotonic state holds the central place.

We see here, as others have emphasized, that the "experimental" researches are shaped and motivated by great speculative forces. Does this mean that science is, for Faraday, ultimately in fact a theoretical enterprize? I think it is only so to the extent that there is a gap which has not yet been filled, as it should be, by something other than such speculative concepts. His own terms in a quotation above are revealing: there is "a link in the chain of effects, a wheel in the physical mechanism of the action, as yet unrecognized." As the gap is filled, the need for theory will disappear. As science takes its completed form, hypothesis and speculation, which is the only sense of "theory" for Faraday, drop out, and a completed "physical mechanism" with no gears missing takes their place. True science, for Faraday, is the machine revealed.

It is useful, finally, to note what Faraday does not ask himself. He does not ask questions about functional relationships: he does not ask, for example, the amount of the repelling force on a diamagnetic body, or the dependence of this on the strength of the field in which it is placed. He does not work with ratios and proportions. Not only does he almost never write an equation: he never asks the kind of question which has an equation as the natural form of its answer.

Faraday's discomfort with the notion of a functional relation in mathematics is revealed poignantly by a remark he made very late in his career, at a time when he had finally been brought into confrontation with the dreaded inverse-square law of gravity. He rebels at the formulation "with a strength VARYING INVERSELY...." The capital letters are his, expressing his outrage at what he considers a blatant violation of the principle of conservation of the force: how can it then "vary"? [14] He understands, indeed, the algebraic relation as describing the effect, but the equation which for Newton and

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13 Lewis Campbell and William Garnett, The Life of James Clerk Maxwell (2nd ed.; London: 1844), p. 200.

14 Faraday, "On the Conservation of Force," Experimental Researches in Chemistry and Physics (London: 1859), pp. 443 ff., where the remark quoted is found on p. 463. The essay is of special interest to the present study, as Maxwell discusses it at length in a letter to Faraday (Campbell, Life of Maxwell, pp. 202 ff.)

many generations of scientists after him had fully characterized the force, seems to Faraday utterly unjust to it. "Why, then, talk about the inverse square of the distance?" he says, commenting on the dismissal of his theory by the astronomer-royal, Sir George Airy; "I had to warn my audience against the sound of this law and its supposed opposition on my Friday evening...[15]

Reference was made above to Faraday's correspondence with Ampère. The following passage from a letter to Ampère, written early in Faraday's career, reveals the extent to which he was aware of the divergence of his concept of science from that of the mathematicians:

> 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... On reading your papers and letters, I have no difficulty in following the reasoning, but still at last I seem to want something more on which to steady the conclusions. I fancy the habit I got into of attending too closely to experiment has somewhat fettered my power to reasoning and chains me down and I cannot help now and then, comparing myself to a timid 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. [16]

Could there be a more revealing contrast between Faraday's steady effort to staisfy his mind with a dense series of "facts closely placed together," and the elegant demonstrations of the mathematical physicist, embodied in the electrodynamics of Ampère? The latter had announced his program at the beginning of his Théorie Mathématique:

> Observer d'abord les faits, en varier les circonstances autant qu'il est possible, accompagner ce premier travail de mesures précises pour en déduire des lois générales, uniquement fondees sur l'experience, et déduire de ces lois, indepeendeamment de toute hypothèse sur la nature des forces qui produisent les phénomènes, la valeur mathématique de ces forces, c'est-à-dire la formule qui les représente, telle est la marche qu'a suivie Newton...c'est elle qui m'a servede guide dans toutes mes recherches....[17]

One should not, I think, be put off by the modesty which Faraday assumes, however sincerely, in this letter. It is clear that he really makes no apology for his physics. It is a science, not of mathematics, but of facts. It does not lack mathematics, for it does not need mathematics. As the letter reveals, Faraday sees mathematics as useful (for others) as a short-cut, in leaping over gaps. His own idea, however, is of a science without such gaps, a science essentially non-quantitative, not needing either mathematical equations or chains of argument, but only intelligent experiment and clarity of view.

Faraday certainly reasons incessantly But for him the motions of the mind are constantly checked by reference to fact, so that the result is a dense structure, a closely-spaced series, directed throughout by experiment:

> Let the imagination go, guiding it by judgment and principle, but holding it in and directing it by experiment.[18]

Throughout the Experimental Researches, it is true, speculation and imagination run ahead of experiment, but seldom by more than a paragraph; this is not theory-building in the mathematician's sense, but envisioning new, possible things, and they are no sooner envisioned, than they are sought.

This is of course a naive view, profoundly naive. Faraday built the world of Experimental Researches according to this naivete, and if we are to view it by any other criteria, or use his work for other purposes, we must first to a certain extent destroy it, and then rebuild. It is, perhaps, the literary triumph of Maxwell's Treatise that it effects this translation of Faraday's thought into mathematical physics with such gentleness and understanding, preserving so much of Faraday's concept of nature and of science.

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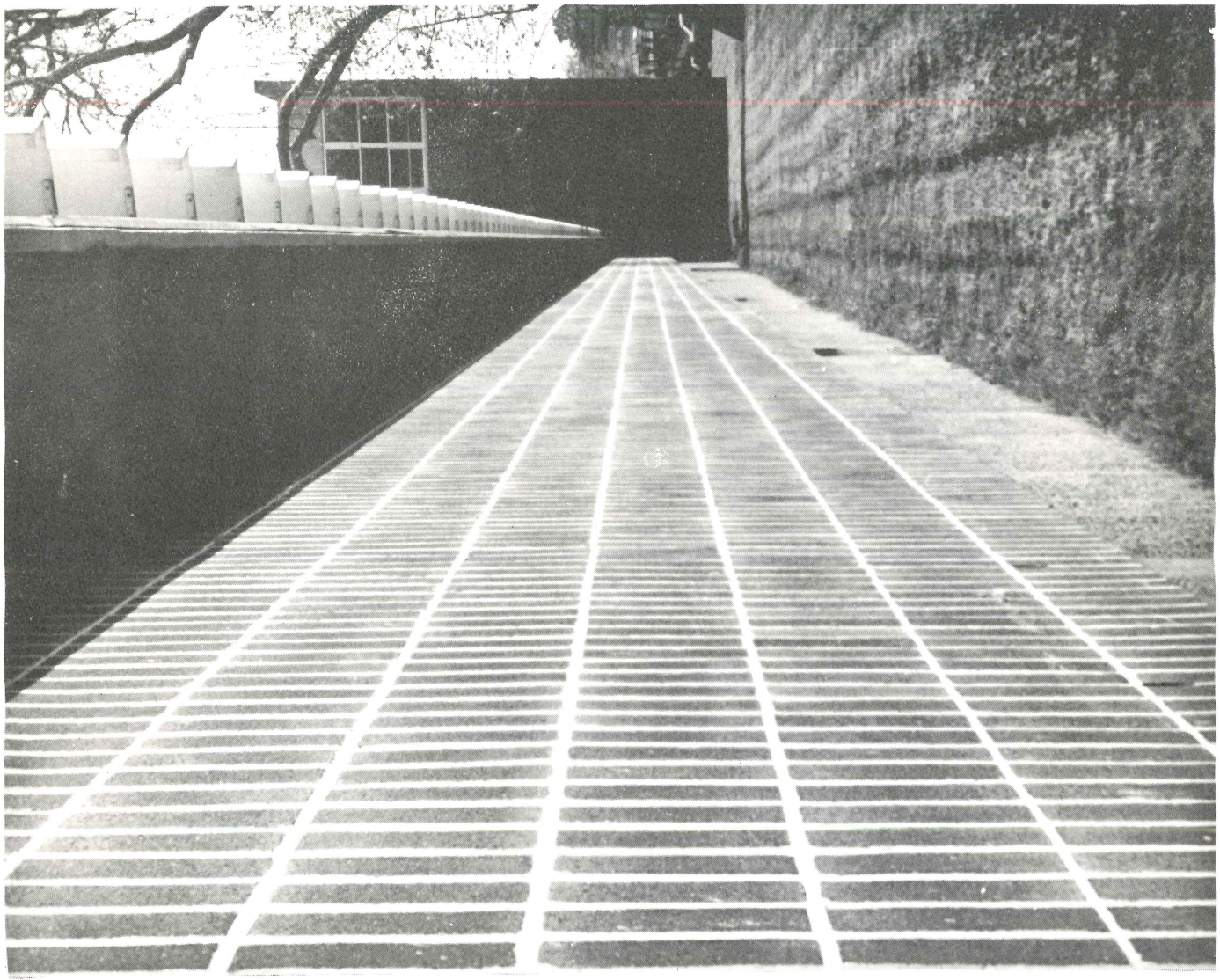
15 Bence Jones, Life of Faraday, 2, p. 354.
16 de Launay, Correspondance, **3**, p. 929.
17 Andre-Marie Ampere, Theorie mathematique des phenomenes electro-dynamiques, uniquement deduite de l'experience (1827) (reprinted Parie: Librarie Scientifique Albert Blanchard, 1958), p. 2 (italics mine).
18 Faraday, Diary, 7, p. 337. The remark in its context in the Diary pages is not a reflection, but a Dionysian outcry in the midst of the chase. It is surrounded by a cascade of ideas, as much speculative as experimental, about a wished relation of gravity and electricity.



Mark Sittler

ATHENS AND KONIGSBERG

Could one man, resting in this very heart
Of Nature, about whose head the planets
Spin in tiny images of some far greater vastness
Could, when he sees the Sun descend, or rather,
Sees the Earth draw up her blind, a dark
Milieu of starry bits and points of light
Scattered through those crystal spheres and caught
Forever; could one man see far enough, and
High enough, to hold that universe within his
Hand, or set it down upon a page? Or rather,
When stars look down on us, could they be
Asking guidance from the man? For who could guess
What Gods we have set loose upon the World? and
Who could dare to open up a box of rules
To hamper Nature as she dances through eternity for us?

Stephen Morse

FOR FRANCES

How many men have tried to walk
Your cobbled heart,
And in a quiet rain, have slipped
And washed away,
Amid a thousand tiny rivers
Of regret?

THOUGHTS OF THE FUTURE

I never meant to ask
Of History a question, yet
All I've learned has been
Of what is past, and what
The minds that left the Earth
Have learned, they said, from
Heaven.
So now there's nothing left for me
Unless it be to leave historic
Personages upon their dusty shelves
And go, and see,
If they will follow me.

STUDY
COMPOSITION
TEXTURE AND
MOOD

Steven Dos Remedios

JUSTA MOMENT

Foxé Jackson

The toe of a new but unpolished loafer smacked the pavement, impatiently splashing slush into craters. Aaron was late. Carolyn leaned against the cold metal post of a street sign and played distractedly with the grey ice water at her feet. We've missed the 5:15; it's dark enough to be half-past and cold enough to be the middle of the night; hurry up, damn you. The wind blew across the city making the gash of each street an open incision. A doorway would break the wind, but I'm not going to give you the satisfaction of having driven me to one. I'll get cold--and then see how cold I can be. The tan trench coat inclined stiffly toward the post; leaning was not the natural posture of the figure beneath it. The poplin was damp, the dampness which turns it to grey but has not yet reduced it to transparency. The misty air threatened to do so, and only the glare from the street light above appeared to defend the still, fragile form by casting translucent shadows. Carolyn's feet tired of their game, and clenching no longer warmed her hands. Her fingers gained the freedom of numbness. One hand found a handkerchief, the other a tube of lip-ice. Ha! They'll bleed before I protect them for him! 5:35. I could take the 5:45 and tell him I didn't wait. Relaxing keeps one's teeth from chattering. I wonder, though, if being tensed wouldn't preserve more heat? The shadows from the street lamp showed snow drifting from the open hand of an oblivious God. God must be like snow: pure, ubiquitous, and cold. Carolyn's left hand had emerged to drop the shreds of the paper handkerchief onto the ice shredded by water thrown from the street. She wouldn't turn, to watch for either Aaron or the bus. Let them come to me. She didn't care which came first; she would know how to react to either. He came from behind her. Footsteps on snow are flabby; they sqush and ooze. I'll tell Aaron he sounds flabby.

"Did you miss me, Darling?"

One hand braced against the pole above her head. Across the other arm rested a long white florist's box. His trench coat fell against hers, the rasp of wet cloth dragging together as rough as his lips on hers. The tube of lip-ice was warm now between her fingers. If you're good, you can get the cap on and off with one hand without messing up the inside of your pocket.

Jim Villere

GAME BY PAIRS

Anthony Snively

I know one motion and that one dimly,
Set for body and the voiceless waves:
Old ghosts who spume in rooms
Where come to be such lithe creations
As the pulse in diverse moments gives.

And winds are set dancing to gentians slithering
Where she spindles younger than the chanting sky
In spindrift August footfall
In music macabre of the lightning's flute
Whose strains the merlin echoes to the tide.

Dancing, chimed motion across a silver web,
And fringed gentians gaming in the sunset
Glance off the checkered tide
And viol its sodden ghosts, suspend in riches
Where kings who die have all died dancing.

Shadow of the plume of consort sky
Bends on the chambered convex of the sight
And on the werewolf mate of winds,
The bow drawn softly by her hands
Rehearsing rondo bloom arising in a step.

Become of her drift and leeward moved
The glittered turns of talis-flowers of the veins
As body torches on the gaze
Where showmen weave their puppet spell
Cajoling stolen kisses from the nightingale;

And of the bubbles of her heart, duet
Of wind and sea unheard within the wilderness.
The soul has but her turn,
That when its ears laugh on the stranded wires
Vortex blood streams through the cresset word.

And this tithe of shades implodes the heart,
Mingles in her hands rook of sand
And bound on benches snow-patterned waves
Which on the choral dust of merlined tombs
The totem doge spins in his trance.

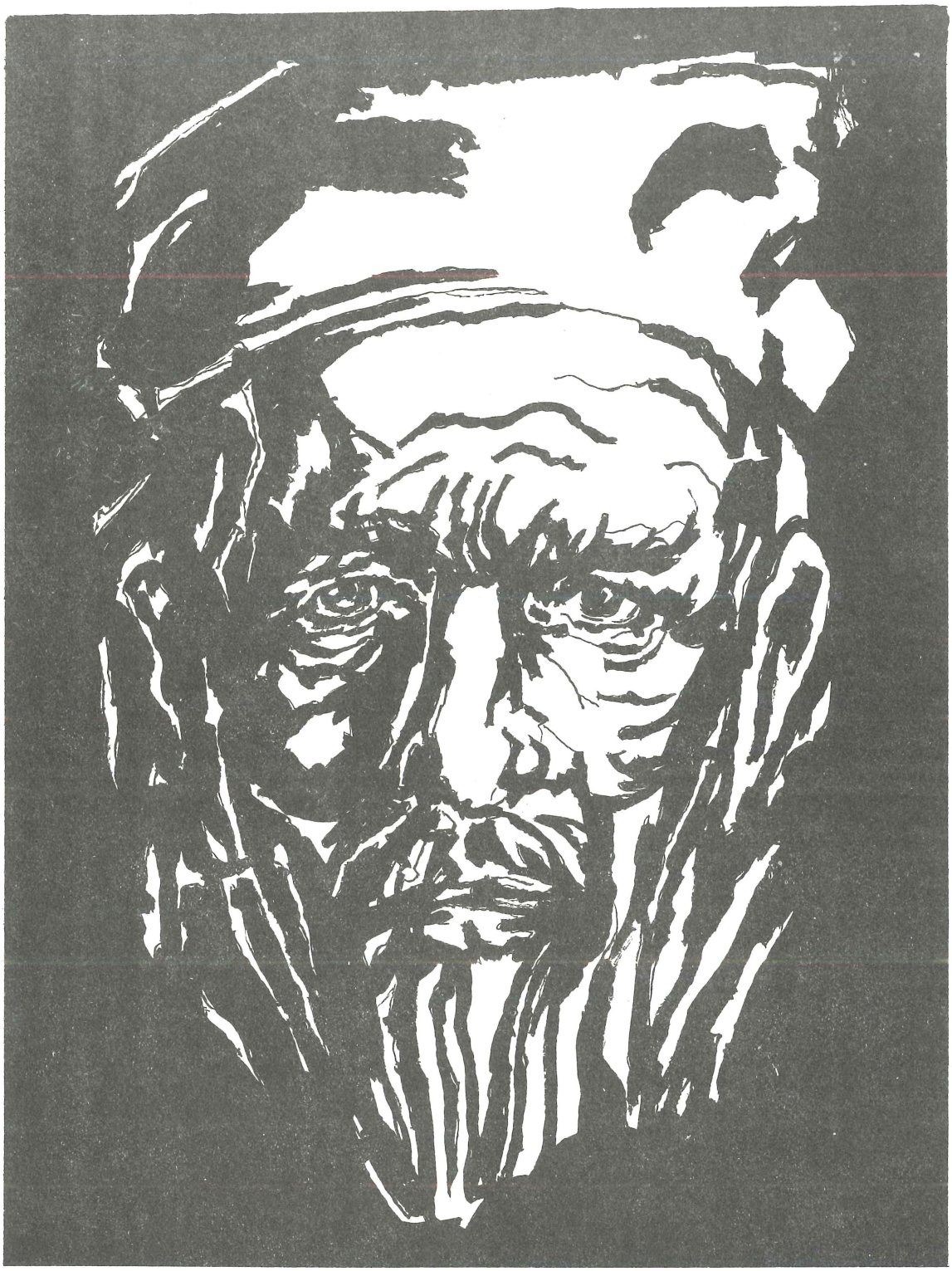
I know one motion: and that one dimly
Told by turns of echoed rocks enwrapt
Where eye is still, the wind veneer
Until the pulses flood the sea-spawned mime
And see the silence pass the siren's call.

SELF PORTRAIT
February 10, 1968
Deborah Massell

SAUL

Saul, with sixty years of age hanging from
His bones, approached a witch's tent in a
Kingdom dying of God. About him his
Guard kept close watch. In the tent he cowered
The hag, forced her to summon the spirit
Of the dead Samuel. Even in the
Eyes of God the supernatural could
Perform, even the damned must have beliefs.
And so out of a cloud of stench the dead
Arose and Saul was condemned, for he did
Not know what to do with the forces of
Israel, and now he knew what would be
Done to him - so that like a pig he fell
To groveling in her dirt parlour. And
His men heard him and came into the tent
To see the hag helping the king to his
Feet. And they brought the king to her table
And fed him and the next day he was slaughtered.

John Dean



Daniel Sullivan

THE POWERS OF DARKNESS

By Anne Lyons

A study of the death motif in Thomas Mann's Magic Mountain

Joachim says to his cousin who is just arriving upon the Magic Mountain, "You're going to see some things you've never dreamed of, just wait".

Chapter II of Thomas Mann's The Magic Mountain,[1] "Of the Christening Basin, and of Grandfather in his Twofold Guise" introduces aspects of Hans Castorp that permit his particular experience of darkness. The christening basin, over which many small, fuzzy heads have sought absolution, introduces the past, the persistent and returning past. The small boy loves to hear his great, old grandfather tell of the successive christenings. The bowl, within the scope of the boy, is something that partakes of eternity and when Hans Castorp's own head was over the bowl he too took part in the returning cycles of eternity.

The boy who becomes the unassuming hero of this strange book also has an early encounter with the less abstract aspect of eternity-death. Hans Lorenz Castorp presents a clean, beautiful appearance to his grandson. To the child the grandfather is old, so old as to be from another era and "something in the depths of the child's being responds to it" (p.20). Yet, the old, wonderful man has a red handkerchief showing from his back pocket. What is that? Han's mother died in a laughing fit; his father passes soon after. By the time Hans Lorenz finds his "pure and genuine form" death "was no longer strange [to small Hans], it was already right familiar" (p.16).

> Grandfather had finally and formally surmounted his interim aspect and assumed for all time his true and adequate shape.
>
> In one aspect death was holy, a pensive, a spiritual state, possessed of a certain mournful beauty (p.26).

This is what Hans has found in the christening bowl, in the portrait of his grandfather, and in his dead grandfather. But the red handkerchief must reappear.

> In another it was quite different. It was precisely the opposite, it was very physical, it was material, it could not possibly be called either holy or pensive or beautiful, not even mournful...almost improper (p.26).

The body was rotting: it didn't smell good. Young Hans knows death in two ways: it permits the true aspect of the once temporal to be revealed. But death, because of flesh, is indecorous, even a bit absurd. Humorous? Can these two ways be understood together?

Again, to go back in time with Hans Castorp to find Hippe, a strange boy, whose name means scythe in German, the instrument of death. The dream Hans Castorp has of Hippe provides the link for us between love, disease and death. After the strange incident of the bench and the bloody nose Hans Castorp returns to the sanatorium from his walk. He is late for Dr. Krokowski's lecture; he finds himself seated behind Clavdia! She's the girl with the arms and the eyes. He listens to Krokowski: ...

> Love suppressed manifests itself in disease and disease has a very intimate connection with death (p.128).

Now, Hans Castorp is impassioned by the diseased Clavdia who is described as an incarnation of Hippe who himself is death. Thus allowing the conclusion that Hans Castorp loves death and this love is now able to manifest itself in lust because Clavdia's disease permits her laxity where Hippe was necessarily silent and restrained. Krokowski continues his talk about love. Mann writes:

> He employed the word love in a somewhat ambiguous sense so that you were never quite sure...whether he had reference to its sacred or its passionate and fleshy aspect (p.126).

This duality is the same as that found within the coffin of Hans Lorenz Castorp. Why is love ambiguous, dual, two-sided in the same way that death is?

The episode in the X-ray room, called a "technological witches' kitchen" by Mann, expands upon Castorp's relation to death and emphasizes death's relationship to love. While the boys wait in the "artificial twilight" of the office, Clavdia comes in, of course. Castorp contemplates the fact that she too is going to be X-rayed, that the inside of her body was going to be revealed.

> He turned away his head and put on a primly detached air; a sort of seemly obscurantism presented itself to him as the only correct attitude in the presence of such a thought (p.213).

His reaction here is similiar to his reaction when he observes a fly upon the corpse of Hans Lorenz.

> Old Fiete shooed it cautiously away, taking care not to touch the forehead of the dead, putting on a seemly air of absentmindedness-of obscurantism, as it were-as though he neither might nor would take notice of what he was doing. This correctness of demeanor obviously had to do with the fact that Grandfather was now no longer anything but body (p.28).

Humans have bodies and bodies are what you make love with and they are what dies. Hans Castorp feels the strange indecency of body alone. The dictionary meaning of obsurantism is "opposition to

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[1] Thomas Mann, The Magic Mountain, Alfred A. Knopf, 1946.

learning and inquiry" from the Latin word meaning "to darken". What is it that Castorp needs to darken? Something, I suppose, that is quite dark already but in the "technological witches' kitchen" and later, will find illumination.

Within the twilighted chamber "where fearful powers were in play" Castorp sees "some things he never dreamed of". Behrens showing a skeleton of a female arm says "that's what they put around you when they make love" (p.215). (And I'm sure that he laughed as he said it.) Then, when Castorp approaches the machine to be X-rayed Behrens says "embrace the apparatus as if it were something else...as though it filled you with rapture" (p.215). Why, in this dark, odd-smelling chamber does the doctor joke about sex? Then before Joachim's "graveyard shape" Hans Castorp becomes upset:

> Yes, yes! I see, I see, My God I see! He was strongly moved by what he saw-or more precisely by the fact that he saw it-and felt stirrings of uneasy doubt, as to whether it was really permissible and innocent to stand here in the quaking, crackling darkness and gaze like this (p.216).

However, when he sees his own hand in the magic X-ray machine he becomes totally unnerved and, as wily Odysseus did, and as everyone must, he saw what up to now he had been obscuring-his own death.

> Hans Castorp saw precisely what he must have expected, but what it is hardly permitted man to see, and what he had never thought it would be vouchsafed him to see: he looked into his own grave...for the first time in his life he understood that he would die (p.219).

So now that Castorp has been somewhat freed of his obscurantism or desire to darken he proceeds to the other extreme. He brings death from darkness into an absurd light. At the sanitorium death is treated with "expert reverence". He resolves to visit all the people who are bedridden and in the extreme of disease. These moribund are presented by Mann in a formal, patterned parade. The two boys watching this parade react in different ways to the entertainment. Joachim says "there must be discipline" (p.234); an order must be adopted or imposed in the face of death or complete fear and absurdity would reign. Joachim dies too soon to realize what is possibly shown at the very end of the book-that disorder will rule anyhow. Castorp treats death in a way as he did as a child. His attitude is similar but he never would have been so ridiculously obvious about something it "is hardly permitted man to see". He says, "I think the world and life generally is such as to make it appropriate for us all to wear black and for all our intercourse with each other to be subdued and ceremonial and mindful of death" (p.295). Actually, we do act mindfully of death, however, not in the way Hans Castorp describes, nor in Clavdia's way, but in a way that Hans Castorp learns in a dream of youth.

But the strange parade of the moribund proceeds. The "overfilled lady" and her laughter and her hopelessness; Frau Mallinckrodt in number 50 who is horribly disfigured but whose "inborn femininity triumphed even over the eczema that covered her face" (p.313). The gauze dressings which she wore about her head became a personal adornment. But did her femininity triumph? Neither the overfilled lady's laughter nor Frau Mallinckrodts's charm can triumph over the darkest thing of all. With poor Karen Karstedt their parade reaches a sad-not really sad but absurd-end. Adopting her as a companion, the cousins take her to watch the bobsled races. Viewing the track, Hans Castorp remarks, "This is where they run the bodies down" (recalling for the reader Castorp's own hysterical laughter when he was first told about this). They take her to the movies:

> It was a thrilling drama of love and death-constructed to cater to the innermost desires of onlooking international civilization (p.317).

So wherever they seek to amuse themselves they find always a reminder of death to which they all stand in varying proximities. When the film is over, and the lights go on, the audience is dazed; they had been taken away for the moment from their own present to another:

> They...stared vacantly before them, blinking in the brilliant light and wishing themselves back in the darkness, but in silence the theatre was emptied and a new audience took the place of that going out, and before their eager eyes the cycle would presently unroll itself again (p.377).

Hans Castorp has previously remarked" ...eternity turns out to be not straight ahead but merry-go-round" (p.371).

Mann says about these episodes:

> So much was true after all, that poor Karen did afford Hans Castorp a substitute (for Clavdia)...as did the rest of his charitable activities (p.319).

So Castorp dances with death when it is not possible to actualize his passion for Clavdia. But, as was said before, Clavdia is Hippe and Hippe is death, so isn't Hans satisfying his lust, just in a strange way?

> The inward satisfaction he experienced whenever he fed the afflicted Frau Mallinckrodt her broth or saw poor Karen clapping her ravaged and mortifying hands...was of a vicarious and relative kind; yet it was none the less pure and immediate... (p.319).

The last excursion made by the three, silly Hans Castorp, poor Karen and Joachim, is a walk in the graveyard. Mann says "we tell it to complete the tale of their excursions" (p.320). It was, of course, Hans Castorp's idea to go there. It is really horrible; it is like Castorp pushing poor Karen to her death. This terrible and grotesque chapter ends with all the moribund that Castorp has visited dying, leaving him free to move to a less vicarious satisfaction of his passion.

The carnival night chapter is introduced with a discussion of the cycles of time. Time returning again upon itself becomes the eternal. When Settembrini is asked by the boys for a description of the carnival celebrations he answers in his usual mockery:

> The program includes various danse macabres...but unfortunately some of last year's guests will not be here (p.322).

His phrase 'danse macabre' throws immediately back to the chapter just discussed, "The Dance of Death". But why, on a night of celebration, does Settembrini evoke darkness? Hans of the dream world gives an answer later in the program.

But who is Settembrini? He who refuses Hans the use of 'thou', he who watches the patients and the doctors too enter a frenzied and distorted dream but remains intact himself. Settembrini is the man who breaks in on Castorp's dark musings with electricity's clear light. Hans, in paying Settembrini a tribute and in saying goodbye to him as a mentor describes him:

> You are not just any man, with a name like another; You are a representative, an ambassador to this place and to me (p.329).

One immediately wonders from where is he an ambassador? Here is another description, also by our Hans, of Settembrini:

> Here was blue-mantled death masquerading as a humanistic orator and when one sought to gaze at close range upon the pedagogic and literary god...one discovered a squatting ape-faced figure with the sign of night and magic on its brow.

Herr Settembrini introduces and is the only character to use the phrase "the powers of darkness" yet within the novel he is characterized as the bringer of reason's light-Lucifer.

But Hans really does not free himself from Settembrini's hold, not until he enters a bit further into darkness. Through the game of drawing a pig with ones eyes shut is contrived a situation for Hans to speak to Clavdia. He needs a better pencil to make a better attempt at the trick. He borrows one from her and so enters upon a dream that brings him second closest to eternity. Through the silent speech of the unfamiliar French language spoken in this dark dream Castorp learns that his dear cousin is really very sick, yet Hans survives this news with enough strength to return Calvdia's tiny red pencil. On this night, the commencement of Lent when flesh is supposedly forsaken, but when Castorp enters deepest into that world, does he do it with his own words in mind?

> Oh, love, you know-The body, love, death, these three make one. Because the body is disease and pleasure and it is both of these that bring death, yes, both love and death are carnal and that is their terror and their huge magic (p.342).

Later Hans contemplates Clavdia's X-ray portrait and begins to relive Walpurgis-Night. A skeleton kindles lust in him-just as Behrens said. But Settembrini speaks of the connection between death and flesh and speaks of an understanding of death in a way that Hans, in the process of his strange education, must finally decide to discard.

> Let mind once dualistically isolate death and death will become in actual fact, 'actu', by this mental act of will, you understand me, a power in itself, the power opposed to life, the inimical principle, the great temptation; whose kingdom is the kingdom of the flesh. You ask me why of the flesh? I answer you: because it is deliverance-yet not deliverance from evil but by evil (p.412).

Death separated from life, as when Hans saw his grandfather rotting or when the mind "erects it into an independent principle, becomes grotesque", a spectre surrounded by such mysterious terrors that the gaze of reason can not even be focused on it. Settembrini however thinks that death, "that most dissolute of powers", can be successfully contained by the powers of reason. "Either the experience of death must be the last experience of life" - this is Settembrini's rather simple and clean answer to the problem- "or it must be a bugaboo" and this is Naphta's most dark and irrational conception. It is both of these and more. Death might be included in life as an experience itself though Behrens says it is not. Death is a bugaboo, but not so simply, though it remains above coherency it does not remain above some strange but actually practical understanding. It remains for Hans Castorp who

> since a child had pictured death to himself as wearing a starched ruff, or at least a sort of half uniform with a stand-up collar while life on the other hand wore an ordinary collar

to comprehend life, disease and death; it remains for Hans Castorp with his desire for life experience, his receptivity to disease and his respect for death, to reconcile Settembrini's clarity with Naphta's total darkness. How does the faceless Hans do this?

He must go somewhere and the merry-go-round that young Hans rides will take him somewhere pretty far away. High on this marvellous mountain, Mann creates his own bizarre circus:

> The snowfall was monstrous and immeasurable, it made one realize the extravagant, outlandish nature of the place (p.471).

Hans lies on his balcony, probably studying, but plans come into his head as he watches the snow, plans that precipitate his real learning.

> The scene blurred more and more, it inclined the eye, gazing thus into woolly vacuity, to slumber. At the moment of slipping off one might give a start-yet what sleep could be purer than this in the icy air? It was dreamless. It was free from the burden-even the unconscious burden-of organic life, as little aware of an effort to breathe this

> countentless, weightless, impreceptible air as the breathless sleep of the dead (p.472).

Hans Castorp's pending dream does not turn out to be as effortless as this sleep, but he does somehow enter the same realm-a silent and dead realm and the lesson he learns in the end is actually simple. So Hans conceives the plan of learning to ski and going out on his own. His friend, Settembrini, encourages the plan but says that he himself cannot accompany Castorp for he is a "broken man". Obviously this journey into what becomes a "blinding chaos, a white dark, a monstrous dereliction...a mad dance" requires the strength and flexibility of Castorp's peculiar youthfulness. In the snow Castorp is totally awed by the vastness, the silence, the whiteness, the primevalness of the mountains. He felt himself presumptuous to be there.

> What he at this moment knew was the fascination of venturing just so far into the monstrous unknown (p.477).

Where is our simple Hans going? Talking about the snowflakes which threaten to bury him, Hans says:

> each in itself-this was the uncanny, the anti-organic, the life-denying character of them all-each of them was absolutely symmetrical, icely regular in form. They were too regular, as substance adapted to life never was to this degree-the living principle shuddered at this perfect precision, found it deathly, the very marrow of death... (p.480).

Here is death, contained within the vast, white land of snow, but "the fear of death [has been] cast out [of Hans] by the irresistible oneness" (p.477). The color of the ice is "the color of certain eyes, whose shape and glance had spelled his destiny" (p.479). "...how alluring and accessible seemed their softly covered gorges and defiles" (p.481). Hans Castorp is going up into the snowy mountains to finally learn about death-but death's dark place in life, and he is being seduced. Through love, he learns about death; "his blood leaps" for

> when a young man has lived years long in the way this one had, something may gather-may accumulate-in the depths of his soul, until one day it suddenly discharges itself with a primitive exclamation of disqust, a mental 'oh go to the devil', a repudiation of all caution whatsoever, in short, with a challenge (p.481).

So, with this lust for knowledge bringing experience, Hans Castorp cannot fail to come to a real and large understanding. And, since he does not need to hold on to anything as Settembrini and Naphta do, he will be able to see it as it really is. "The storm burst, the storm that had threatened so long" (p.482), the storm caused by the dissatisfaction inherent in the incomplete philosophies of such as Settembrini and Naphta. This is a private storm for any human being who really confronts life. It is also a larger struggle for an institution, a nation or a culture which has built and grown beyond its own understanding or beyond its own ability to comprehend and accommodate itself.

The storm increases; visibility decreases. Hans Castorp is slowly cut off from the world below. Now even the sanatorium is part of the world below. As his extremities freeze and his features numb, Castorp moves closer to a strange freedom. He is alone and talking to himself:

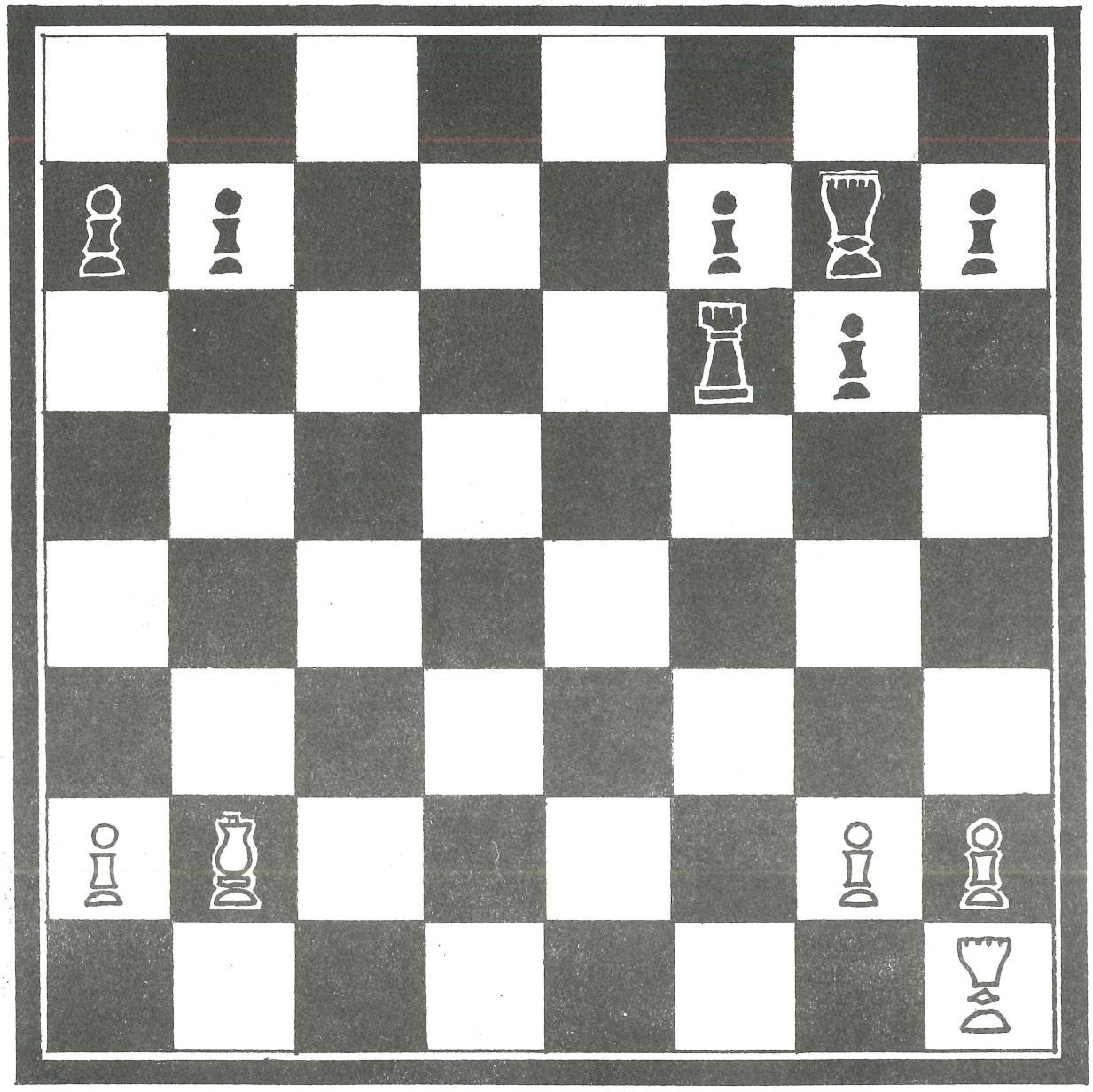
> You went in a circle, gave yourself endless trouble under the delusion that you were accomplishing something and all the time you were simply describing some great silly arc that would turn back to where it had its beginning (p.487).

But there is something perfectly whole and eternal in the end point of the circle. After having arrived at the landmark of his circle, after having arrived in the realm of the eternal, Hans Castorp has his dream. The whiteness of the storm increases, but the sun is setting, letting darkness come. Hans Castorp becomes confused; he slowly slips away from clarity into his dream. "It was a park", His dream is light, "...the glory of light", yet a place that contains only light is the darkest possible place. The people of Castorp's dream are lovely youths but Hans feels that "it is not alone the outward form, they seem to be wise and gentle through and through" (p.492). What is their wisdom that creates their beautiful countenances? These children of the sun are children of light. Would Plato say they then are children of knowledge? But their knowledge is of darkness. A youth indicates the source of darkness to Hans, the intruder. As Hans watches the youth's face "in his gaze there came a solemnity that looked as though carven out of stone, inexpressive, unfathomable, a deathlike reserve which gave the scarcely reassured Hans Castorp a thorough fright, not unaccompanied by a vague apprehension of its meaning.

> Two grey old women, witchlike, with hanging breasts and dugs of finger-length, were busy there, between flaming braziers, most horribly. They were dismembering a child. In dreadful silence they tore it apart with their bare hands-Hans Castorp saw the bright hair bloodsmeared-and cracked the tender bones between their jaws, their dreadful lips dripped blood (p.494).

This is the center, the source of all darkness if it remains undiscovered, but the center of light if it is found. Facing, admitting, knowing death and dark things one can live one's life in light. But to remain ignorant means to be continually dissatisfied. Our hero comes full circle and "knowing the body, knows death" (p.495). Hans Castorp realizes the places of love and disease and death in life. "All interest in disease and death is only another expression of interest in life" (p.495). "I have dreamed of man's state" (p.496) says Hans. "I will keep faith with death in my heart for the sake of goodness and love. Man shall let death have no sovereignty over his thoughts".

Castorp awakens! and his dream quickly fades. He has died into himself and found there the temple of his body. He found there the container of death. As the surroundings of the temple are light and lovely, so is living varied and wonderful. But just as the youths live with their blood sacrifice within, so each person contains death within his body. "You're going to see some things you never dreamed of", says Joachim to Hans as he first arrives.



White to play and win

David Roberts