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Essentialism and Effluvia 1700-1740: A Thematic Study

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ESSENTIALISM AND EFFLUVIA 1700-1740:

A THEMATIC STUDY

BY

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Abstract

There have been many explanations offered for the transformation which occurred in natural philosophy during the sixteenth and seventeenth centuries. One such explanation was that this "scientific revolution" was philosophical, i.e. the changes which occurred in natural philosophy were marked by the transition from an essentialist to a non-essentialist view of nature. The validity of this explanation was investigated by selecting an essentialist theme, effluvial theory, and tracing its development from its origins in Renaissance occult philosophy to the incorporation of effluvia into the physical theory of the 17th and 18th century natural philosophy. This was accomplished by use of the thematic analysis as developed by Gerald Holton.

From this analysis, it was concluded that effluvial themes persisted throughout the period and were incorporated into the natural philosophies of Isaac Beeckman, Isaac Newton and Stephen Gray. The widespread application of effluvia themes by men of such differing views of nature led to the rejection of the proposal that the post-revolutionary period could be characterized as non-essentialist. Finally, with regard to the presence of the effluvia theme in the work of Gray, it was found that the electrical effluvia was the unifying principle in his natural philosophy.

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To Diane

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Introduction

In a recent article published in ISIS (1), Margaret Osler discusses the role of Galileo in the transition from medieval to modern science in terms of a shift in the epistemological basis of science. This shift from essentialism to nonessentialism, she says, is "a characteristic feature of science during the scientific revolution." (2) Such a shift in the foundations of science, if it in fact occurred, would indeed be revolutionary, and would be suggestive of a large scale paradigmatic change occurring in the 16th and 17th centuries. Certainly, the notion of a sharp transition between medieval natural philosophy, which dealt with the nature or essences of things, to modern science, which claims to deal only in phenomena, is appealing if only for its simplicity. To be sure, Ms. Osler points out that nonessentialist views of science preceded the scientific revolution. The thrust of her argument, however, is that pre-revolutionary science was essentialist, and post-revolutionary science was not. Galileo, as a scientist in the midst of revolution, reflects the transition between epistemologies in his personal scientific development.

To evaluate the validity of this argument, one must first consider the role of epistemology in the methodology of science. Certainly, with regard to the individual scientist, questions of what constitutes knowledge will limit and direct his researches. In this respect, the matter of Galileo's essentialist attitudes serves as a good

example. It is quite reasonable to assume that an essentialist would have been totally unconcerned with the equations describing the trajectories of falling bodies. Thus, insofar as Galileo was concerned with kinematics, he was behaving as a nonessentialist. But, whatever motivates the individual investigator is, to a certain extent irrelevant to the overall development of science as viewed in the contingent plane of phoronomic and analytic concepts.(4) Public science is concerned primarily with these two types of propositions, and, thus, communication among members of a scientific community would tend to remain on this plane. This is not to deny the importance of philosophic, aesthetic, sociological or psychological considerations in examining the development of science. To be sure, they are of great importance. The input of such considerations in scientific development is not normally regarded as a part of "scientific inquiry" by scientists themselves. This fact helps to account for the somewhat dry nature of scientific prose.

It is important to recognize the fact that most communication among scientists occurs within this rather narrow range of the "scientific". Non-scientific, or thematic, elements, which were so vital in the development of the scientific ideas in the first place are usually omitted when the scientist relays these ideas to his peers. The thematic elements are still there, hidden beneath the

paradigm. Since thematic attitudes are not directly transferred, it is unwise to infer that the epistemology of a scientist is necessarily shared by the whole scientific community. (5)

Yet, Kuhn (6) correctly points out that the very success of a certain approach to science fosters further research done in the same, or similar ways. It is certainly possible that in this sense there is a body of shared thesata within a scientific community. In fact, these thesata help define the group. Such shared preceptions are analogous to Kuhn's paradigm and would be transmitted in much the same manner. One might contend that epistemologies can be shared thesata, and the shift from essentialism to nonessentialism is analogous to a change in paradigm. In order to prove this contention, however, it would be necessary to examine the post-revolutionary period to see if it could really be characterized as nonessentialist. This is not an easy task, since, as was mentioned earlier, thesata are not usually evident in public science. But as Holton points out, "the thematic component is most obvious when a science is young" (7), so that an investigation into some newer aspects of post-revolutionary science might reveal the epistemological preceptions of the investigators. The following study of electrical theories in the eighteenth century is just such an investigation.

I

The origins of the ideas about virtues and effluvia in natural philosophy lie shrouded in the mists which divide magic and science. It appears they arose from an aspect of magic known as sympathetic, or natural, magic. In this pseudoscientific approach to occult philosophy, "every object in the world was full of occult sympathies." (1) These sympathies produced certain effects upon those bodies linking them to particular powers found in the celestial sphere. These sympathies were transmitted from the celestial world by means of effluvia "continually pouring down on the earth from the stars." (2) The aim of the natural magician, then, was to channel or direct these influences to accomplish his ends.

This approach to the occult finds its best known expression in the Asclepius, an anonymous work dating between 100 and 300 A.D. Within the Hermetic tradition, this work served as the basis for most of the magical literature of the Middle Ages and the Renaissance. It was widely believed during the Renaissance that the Asclepius and, indeed, the whole of the Corpus Hermeticus could be traced to the magic of the ancient Egyptians. (3) The magic described in the Asclepius has two purposes: first, the control of nature and second, for its worship. Both these ends were accomplished by the same means so that, in practice, they were one. The framework of sympathetic magic

was fitted into an astrology which, in fact, had its origins in Egyptian culture (4), and this astrology provided a basis for the unification of all the various aspects of the occult sciences.

The influence of Hermetic ideas was quite extensive in the Renaissance. They are an integral part of the philosophies of men such as Ficino and Pico, and, aside from their impact on Renaissance magic and philosophy, had a profound effect on medical and, as we shall see later, scientific thought. Francis Yates has traced the development and spread of these ideas in her work Giordano Bruno and the Hermetic Tradition so there is no need to do so here. Ms. Yates contended that one of the chief agents for the dissemination of Hermetic ideas in 16th century Europe was Giordano Bruno, and traced the spread of these ideas through him to England, France, and Germany, as well as his native Italy.

While it is fairly easy to describe the influence of Hermetic ideas of natural magic and effluvia on metaphysics, it is rather difficult to discern their influence upon natural philosophy. This is mainly due to the large thematic component of these ideas, for, as mentioned earlier, theata are seldom stated explicitly in a scientific work meant for public scrutiny. One way of tracing this development, however, is to examine the use of such terms as effluvia and virtues in scientific literature

to see how their connotations change over time, and noting what characteristics these concepts seem to gain or lose. To do this, it is necessary to form a clear understanding of their use in occult philosophy. In the Hermetic universe, all matter on earth was linked to particular planets, stars, and constellations through which the material world shared in the divine forces of the universe. The qualities derived from the celestial realm were called virtues, and their means of transmission were the effluvia. Certainly, the philosophy which employed such concepts is essentialist, for it was the virtues which made matter appear as it does. If one could control or charge the virtues present in matter, he could change its essence. This assumption formed the basis of alchemical theories of the transmutation of base metals, among other things. In fact, it was the basic principle of natural magic. The magician hoped to direct effluvia in ways of his own choosing in order to achieve total power over the material world. By controlling the virtues present in bodies, he could exercise power over those bodies. Obviously, such hopes were never realized on such a grand scale as the total control of the universe. It is important to recognize, however, that the limited control and channeling of natural phenomena is a very real object of scientific activity. This is not meant to imply an equivalence between the scientist and magus, but it is possible to see parallels in the goals toward which each

strives.

Johannes Kepler provides a good example of the transition from magus to scientist. His career reveals a man whose ideas seemed to oscillate between mystical and magical descriptions of nature on the one hand, and statements of natural philosophy on the other. It would seem that there was little or no distinction between the two approaches for Kepler himself. Impressed by Gilbert's description of the "virtues of the magnet" (5), as well as his identification of the Earth and the magnet, Kepler "explained gravity, like Gilbert, as the action of the Earth, which was a great magnet, by means of immaterial material." (6) Kepler goes beyond Gilbert. In his heliocentric universe, Kepler attributes the motion of the planets, described by his three laws of planetary motion, to the force of the magnetic effluvium acting upon the planets. Now, in Kepler, the concept of heliocentricity is associated with mystical notions of God's presence in the universe, so that these magnetic effluvia retain their occult connotation even when used to describe the physical motion of the planets.

Throughout the 17th century, effluvial explanations of natural phenomena grew in breadth and complexity. Nicolo Cabeo (1585-1650) described the action of the electrical effluvium upon matter in much the same way as Kepler used the magnetic effluvium. "He held that from electrum or any

body containre electricity there flows off a most tenuous effluviu which is diffused through the air, but then returns to the electric body and brings with it straws and other particles that it encounters." (7) As effluvial explanations became more prevalent in natural philosophy, the occult aspects of the effluvia diminish in importance. Robert Boyle believed that the collision of the magnetic effluviu with atoms emitted from the stars was the cause of light. Effluvia were still considered immaterial, but natural philosophers began to treat them in much the same way as they did material objects.

As Cartesian natural philosophy became dominant in continental science, effluvial explanations achieved a new importance. Isaac Beeckman (1570-1637), a friend and associate of Des Cartes, used a single effluviu to explain heat, gravity, and magnetism.

Beeckman adopted the hypothesis, which varied somewhat as time went on, of a very subtle matter, ether, air, spirit, fiery particles or celestial corpuscles and effluvia which filled and animated the world, and which served to explain the problems of the vacuum, falling bodies, and magnetic action. As he wrote in his Journal of 1616, 'It does not rest on anything but passes without obstacle...' (9)

While Beeckman's notion of the corporeal nature of this effluviu was muddled, he did suggest a new property of

effluvia. In addition to being the cause of the various phenomena mentioned earlier, Beeckman considered this effluvia the cause of action at a distance. Indeed, the effluvia is the essence of space itself.

This same idea was restated in a Cartesian treatise on natural philosophy written in 1656 by a Jesuit, Pierre Gaufruche, Philosophiae ac Mathematicae Locus ad Ursu Studiosae Inventus. In it he enumerated the underlying principles of Cartesian physics:

The sphere of activity of natural
and their action reflected and refracted
is twofold: by local action only and
by virtue or active quality diffused
from them through the medium... It
(the virtue) is more intense near the
agent... Under this category much is
commonly supposed to be accomplished
by sympathy and antipathy, but also by
occult and specific qualities. Mac-
netic virtue easily takes first place
among specific and occult qualities...
Action at a distance is possible by
such diffusion of virtue, occult qual-
ity and sympathy and antipathy.(10)

To be sure, Gaufruche's effluvia were not as general as Beeckman's, but, they accomplished the same thing. Separately, each effluvia was responsible for only a limited number of phenomena, but together they became the principle of action in the universe.

Gaufruche's notion of many different effluvia was shared by other natural philosophers, both theoretical and

experimental. Lu Daniel spoke of "iridicrific effluvia, responsible for the transmission of cold." (11) Berradding Scrazzini, in 1691, ascribed various barometric changes to the action of celestial effluvia. (12) There were electric and magnetic effluvia, as well as effluvia responsible for light and heat. One noted experimentalist, Otto von Guericke (1602-1686), made extensive use of effluvialist explanations in his New Magdeburg Experiments published in 1672. Thorndike writes:

Von Guericke's volume also treated of mundane virtues. These were neither substances or accidents but effluvia which were in bodies and flowed out of them. But there was this difference between those originally in a body and which streamed from it, that in the latter case they were accidents, while they were innate virtues of the bodies from which they came and could not absent themselves without great detriment or loss of its form... The former could not pass through metal or glass. Examples of incorporeal virtues were impulsive, conservative, directive or magnetic, turning or rotating, scolding heat and light. (13)

By now it must be obvious that the meanings of virtue and effluvia had changed considerably from the original, magical connotations. Although still essentialist in nature, effluvia are now used to describe the interactions among bodies rather than the action of celestial and divine influences upon mundane objects. One cannot deny the occult

aspect of these effluvia, but the extramundane connotation of their effects has diminished if not vanished entirely. By the end of the seventeenth century, the effluvium had taken its place beside the vortex as an accepted "scientific" explanation of natural phenomena.

These Cartesian ideas concerning the nature of effluvia varied among natural philosophers. To some, the effluvia were dense and material, while to others they were immaterial. There was a third group of natural philosophers, among them von Guericke, who held to the idea of the existence of both types of effluvia. This lack of precision in the definition of a scientific concept is by no means unusual. According to Kuhn, it is characteristic of a stage of scientific development in which paradigms are changing or a new paradigm is emerging. If Kuhn's approach has any validity, one must concede that the 17th century is a critical period in the development of natural philosophy, and, therefore, it is not surprising that the concepts that were being articulated during the period were vague. Further, it should be reemphasized that concepts like effluvia have a strong thematic component, and one would expect the thematic element to vary from scientist to scientist. Nevertheless, the general notion of an effluvium was shared by many natural philosophers of the period despite differences in the details of application of the particular effluvium.

II

But what of the new paradigm? Does the Newtonian synthesis which occurs at the end of the century resolve these conflicting ideas about effluvia? Hardly. Newton's published scientific works contain only a few references to effluvia in the Opticks and the Principia, but they are significant since they concern the preconceptions of Newtonian science. Natural philosophy, as Newton conceived it, was quite different from that of the Cartesians. As Koyre points out, "Newton's thought, nearly ab ovo, had been formed and developed in opposition to that of Des Cartes." (1) This opposition not only points towards dissimilarities in the thoughts of the two men, but, more importantly, relates directly to the development of the concept of effluvia.

In contrast to later Cartesian natural philosophers, Des Cartes himself would allow matter only the quality of extension, and completely excluded the idea of any inherent qualities present in matter which would account for its properties (2). For Des Cartes the universe was a plenur. Motion was relative, and occurred only through the contact of one object on another. This would seem to exclude effluvia from Cartesian science. Later Cartesians, however, advanced the notion of effluvia (corporeal and incorporeal) as a basis for certain phenomena, especially those involving action at a distance.

Newton rejected violently this mechanistic universe. Throughout the Principia, he disputed the Cartesian claims on mathematical grounds, insisting that the universe which Des Cartes described could not be identified with the physical world. The phenomena that we know to exist simply could not be produced by the Cartesian model. As strong as this objection might seem to the modern reader of the Principia, it was not Newton's main objection to Cartesian Natural philosophy. Newton's basic objection, as Koyre notes (3), is philosophical, and ultimately, theological. The Cartesian universe, if it had a God at all, requires a deity who is removed from the universe completely - there simply is no room for him. In the concluding General Scholium to his Principia, Newton challenged this preconception:

...God is the same God always and everywhere. He is omnipresent not virtually only, but substantially; for virtue cannot subsist without substance. In Him are all things contained and moved; yet neither affects the other. God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God... All that diversity of natural things which we find suited to different times and places could arise from nothing but the ideas and will of a Being necessarily existing. (4)

Newton's God is not only present in the world but He

takes an active part in its operation. He acts in it by means of non-material forces and, thus, is the ultimate cause of all natural phenomena. The mechanism for divine action is the now famous aether, which Newton describes in the Principia

And now we might add something concerning a most subtle spirit which pervades and lies hid in all gross bodies: by force of action of which spirit the particles of bodies attract one another at near distances, and cohere, if contiguous; and electric bodies operate to greater distances, as well as repelling and attracting the neighbouring corpuscles; and light is emitted, reflected, refracted, and heats bodies; and all sensation is excited, and all members of animal bodies move at the command of the will, namely, by the vibrations of this spirit, mutually propagated along the solid filaments of the nerves, from the outward organs of sense to the brain and from the brain to the muscles. (5)

This passage appears at the very end of the Principia and, along with the General Scholium of which it is a part, stands in sharp contrast to the bulk of the work which is cast in strict mathematical formalism. Yet the transition in style in no way implies a discontinuity of thought. Newton was well aware that mathematical reasoning could reveal inconsistencies in a theory, as was the case with the Cartesian vortices, or with regard to the wave nature of light

The last Propositions respect the action of light and sounds; for since light is propagated in right lines it cannot consist in action alone (by Prop. XII and XIII). (6)

Further, given the form of a force, for example the inverse square law of gravitational attraction, one can deduce the effects of the force on matter and by a mathematical analysis of bodies moving in a gravitational field arrive at the laws of planetary motion. But such an analysis cannot prove that the inverse square law is the exact form of the gravitational force, or that the laws of motion derived from it are followed exactly by bodies in the universe. In the case of planetary motion, it is clear from the Principia that Newton felt they were not. Even in the absence of matter to retard the motion of the planets, Newton believed that the system would eventually slow down.

And, therefore, the celestial regions being perfectly void of air and exhalations, the planets and comets meeting no sensible resistance in those spaces will continue their motions through them for an immense tract of time. (7)

Finally, Newton knew that the mathematical analysis provided no information at all about the causes or properties of the initial forces

...but though these bodies may indeed continue in their orbits by the mere laws of gravity, yet they could by no means have first derived the regular position of themselves from those laws. (8)

These deficiencies in the analytical structure of the Principia were remedied by the introductory Definitions and the concluding General Scholium, and it is in these places that one would expect to find statements as to the nature of matter and forces. Far from being ancillary, these sections made the Principia a study in physical theory rather than an exercise in applied mathematics.

One finds a similar structure in Newton's other major work, his Opticks. Instead of regulating his assumptions about the nature of matter to a General Scholium, Newton couched such speculations in the form of rhetorical questions, or Queries, at the end of Book III. It was in the Queries that Newton again postulated the aether as an underlying cause of motion in the universe. (6) There he maintained that "the Refraction of Light proceed(ed) from the different density of this Aethereal Medium" (Qu. 19), and that the aether was the cause of gravity (Qu. 21), vision (Qu. 23), and muscular action (Qu. 24). Finally, as in the Principia, Newton related his physics to his belief in the presence of God in the universe by means of an

aether-filled space. (10)

Newton's speculations concerning the aether were very concise in both the Principia and the Opticks. The impression that they leave upon the reader, however, is the consistent image of an immaterial effluviu[m] filling all of space and acting upon matter so as to give rise to a number of forces and phenomena which themselves may be described by exact laws. The consistent association of the aether with God leaves little doubt of its occult aspects. Newton believed that the aether acted on matter by means of its vibration or pressure. In his notes on Hooke's Micrographia, for example, Newton described the role of the aether in producing gravity

of gravity, ye Aether (its action being
incorporatus to all other bodys) forcing
bodies to retire from those places where
it is in greatest plenty towards ye Earth
where it is in the least plenty. (11)

Despite the brevity of Newton's aethereal speculations, there can be little doubt that he meant them to be considered seriously as an integral part of his natural philosophy. In addition to the works already cited, one finds references to the aether in a letter to Robert Boyle (12) dated February 28, 1678/9 and in two letters to Henry Oldenburg (13,14) dated December 7, 1675 and January 25 1675/6. Newton also incorporated the aether into his

matter theory in two unpublished manuscripts, De Gravitatione et aequilibrium fluidorum (15) and De Aere et Aethere (16). Finally, Newton, to call attention to his aethereal hypothesis, advertised the second edition of the Opticks, 1717

In this Second Edition of these Opticks I have omitted the Mathematical Tracts publish'd at the End of the former Edition, as not belonging to the subject. And at the end of the Third Book I have added some Questions. And to shew that I do not take Gravity for an essential Property of Bodies, I have added one Question concerning its Cause... (17)

The "electric and elastic spirit" (18) which Newton referred to as "this Aethereal Medium" (19), bears a striking resemblance to Beeckman's effluviu. There can be little doubt that it possesses the general characteristics which we have associated with effluvia, i.e. an essentialist quality emanating from some bodies and affecting others. As with Beeckman's effluviu, the aether was responsible for a large number of phenomena. Since Newton associated his aether with the Divine presence in the universe, one can hardly deny the occult character of this effluviu. In this respect the aether resembled some of the early effluvia, and, because of this, Thorndike referred to Newton as "the last of the magicians." (20)

Clearly, then, effluvial themes were of great

importance in the development of natural philosophy in the seventeenth century. We have seen their use in the two great systems of natural philosophy of the century, those of Newton and Les Cartes. The fact that the notion of effluvia remained virtually unchanged throughout the century, as well as the dominance of the theme in the science of the period would appear to refute Ms. Osler's argument that the Scientific Revolution of the seventeenth century was, in part, a shift from essentialist to nonessentialist natural philosophy. Yet, one must ask if post-Newtonian science underwent such a philosophical transformation. After all, Newton himself seems to have moderated, at least publicly, his views about the nature of the aether especially in Query 21 of the Opticks

And so if any one should suppose that Aether (like our air) may contain Particles which endeavour to recede from one another (for I do not know what the Aether is)...(21)

Further, Schofield maintains that "neither repulsion nor aether provided any inspiration to early eighteenth century investigators to extend Newtonian matter theory into previously unexplored regions."(22) It seems rather doubtful that a theme which was so popular and successful in the seventeenth century would be so completely abandoned in the eighteenth. Yet, Schofield's comment could still be

generally true within the context of British natural philosophy, and still not rule out the importance of aether-like effluvia in certain areas of 18th century natural philosophy. It is not my intention to enumerate all such areas even in the narrow sphere of British natural philosophy; however, since the aether was to play such a large role in the later development of electromagnetic theory, it might be interesting to see how this theme fared in this area in the first quarter of the 18th century. Such an inquiry inevitably leads one to the work of Stephen Gray.

III

Stephen Gray is among the better known electrical experimenters of the first half of the eighteenth century. Yet, although he is often mentioned in histories of science of the period, Gray is usually regarded as a pure experimentalist, as if such a scientist could actually exist. Such a view of the man is understandable since, as Schofield points out, "Gray was exceedingly careful to avoid, in print, any obvious commitment to theoretical explanations." (1) Despite this lack of direct theoretical speculation in Gray's work, we must inquire more deeply into his thought. After all, Gray's electrical experiments dominated the research in the field for the first four decades of the eighteenth century. (2)

Unfortunately, biographical information about Gray is scant. Indeed, the best documented incident about the life of Stephen Gray appears to be his end. Prefacing Gray's last communication to the Royal Society is the oft quoted phrase "taken from his mouth by Cromwell Mortimer, M.D., R.S. Secr. on Feb 14, 1735-6 being the day before he died." (3) Aside from the brief biography of Gray by John I. Heilbron which appeared in the Dictionary of Scientific Biography, the major biographical discussions of Gray are to be found in three articles which appeared in ISIS by Chipman (5,6) and Coker (7). Although the information about Gray's life is sketchy, certain biographical data relates

directly to our inquiry into the development of the effluvial theme in Gray's thought.

Gray was born around 1666/7 in Carterbury into an artisan family. Like most natural philosophers of the period, he seems to have received no formal training in science, and was, as his father, a dyer by trade.(8) Gray may have received some informal training from the royal astronomer, John Flamsteed. Gray's association with Flamsteed was quite long. The correspondence between the two men spanned a seventeen year period as reflected by documents contained in the Flamsteed MSS at the Royal Greenwich Observatory. These twenty-four surviving letters addressed to Flamsteed have been catalogued by Chipman.(9) The last of these is dated 1715/16, some three years prior to Flamsteed's death. The letters were devoted mainly to astronomical observations made by Gray, but, amidst the descriptions of sunspots and eclipses, there are personal references which are invaluable to the biographer. For instance, they reveal that, between 1707 and 1708, Gray spent some time at Cambridge as an assistant to the famous first generation Newtonian Focser Cotes aiding in the establishment of an observatory there. This association with Cotes is somewhat puzzling, for Gray's public success seems, in other instances to run antiparallel to Newton's. According to Chipman(11), Gray's contact with the Royal Society was interrupted for a period of 24 years, a period

which began when Newton became president of the Royal Society and ended shortly after Newton's death in 1727. Not only did Gray fail to publish during this period, he also petitioned Hans Sloane, then the Secretary of the Royal Society, for aid in obtaining a pension from the London Charterhouse in 1711. Gray's appointment came eight years later in 1719. On the other hand, Gray's fortunes rose swiftly after 1727. In 1730, accounts of his electrical experiments began to be published in the Philosophical Transactions. In 1731, Gray became a demonstrator for the Royal Society. He received the Copley medal in 1731 and 1732 at which time Hans Sloane was administrator of the Copley trust. Finally, in 1733, Stephen Gray was elected a Fellow of the Royal Society.

Chipman(12) ascribes this rather curious set of circumstances to the influence of Newton, and, more specifically, to Newton's well publicized feud with Flamsteed. Gray, Chipman contends, was ostracized from public science in England merely for his friendship with the royal astronomer. Now, Newton's vindictiveness is well known, but, if this is yet another instance of it, how does one explain Gray's appointment as Cotes' assistant in setting up the observatory? Newton not only approved of the project, he even donated a pendulum clock to the observatory which was to remain uncompleted.(13) Perhaps the disagreement between Newton and Gray went beyond Gray's

friendship with Flamsteed. Even Chirner is surprised to find no mention of Newton in the following portion of a letter which Gray sent to Flamsteed and which is found in volume 32 Flamsteed MSS 1726/7 (14)

...I hope you will continue with us yet many years and not only live to see your works Published but likewise reap some Benefit of your indefatigable Labours besides that Eternal Commendation that will always be due to your Memory for notwithstanding the opposition and aspersions you have mett with from Ignorant Malicious or unjust detractors who may have Inveighed to Depreciate your Performances Posterity will know how to value them and see that though Copernicus Tycho Kepler and Hevelius have done much toward the advancement of Astronomy yet you have done much more...

If the disagreement with Newton was personal, Gray's letter or his biographies offer no clue. Perhaps, as Heilbron maintains, "the conjecture that Newton somehow delayed Gray's entry into the Charterhouse ... is baseless" but the coincidences impel one to question whether the work Gray published after Newton's death reveals any motive for animosity.

But before undertaking this analysis, there is one further element of Gray's biography which raises a question relevant to our inquiry. Almost from the outset, the bulk of Gray's researches seem to be in the field of astronomy.

Then there appears to be an abrupt transition in which astronomy is replaced by electricity as Gray's main area of interest. This change is reflected in the list of published works of Gray compiled by Cohen(16). Of the twenty-one publications listed by Cohen, none of those published prior to 1706 deal with electricity, and, of the works published from 1720 until Gray's death in 1736, only one deals with astronomy. Where the transition in Gray's interests occurred, if there is in fact a change of interest, is hard to tell from the dates of publication due to this 14 year gap. On the basis of a letter by Gray to Hans Sloane which was not published but was dated January, 1708(17), it is evident that it could have occurred around 1707. This early account of Gray's electrical experiments was sent to Sloane at a time when Francis Hauksbee was demonstrating his electrical experiments before the Royal Society, and Sloane referred the paper to him. Instead of approving of it for publication, Hauksbee incorporated its novelties into his own researches into the subject(18). Hauksbee's work(19) was strongly supported by Newton, and such action by Hauksbee was probably a further source of animosity between Gray and Newton. But why the sudden change in interests, or was there really a change? The answer, again, is to be found in a thematic analysis of Gray's writings on electricity. Fortunately, they are readily available, the bulk of them appearing in the Philosophical Transactions.

IV

If one were to accept Ms. Csler's assessment of post-revolutionary science, as well as Schofield's characterization of Stephen Gray as a mere experimentalist, he would expect Gray's published works to be rather phenomenological. Further, given the nature of the subject Gray was investigating, static electricity, he would expect the papers to deal mainly with the obvious manifestations of static electricity, the sparks and noise which accompany an electric discharge. Nothing could be further from the truth. These observations occupy only a small fraction of Gray's communications, and assume importance in his work only towards the end of his scientific career.

Gray's approach to the study of electricity is decidedly effluviaalist. This may be seen superficially by his use of effluviaalist jargon, e.g. "Electrick Effluvia" and "attractive Vertue", throughout his work. But, beyond this obvious relation to the work of earlier effluviaalists by the use of the same terms, there is a commitment to effluviaalism which is reflected in the manner in which Gray approached his subject, in the choice of experiments he performed and chose to communicate to the scientific community.

With the exception of the last four communications to

the Royal Society (G6-G9)*, the bulk of Gray's electrical studies falls into two categories. The first of these are experiments designed to determine which kinds of material may be classified as "Electrick Bodies", i.e. which kinds of things can be electrified. The second are those experiments which were designed to "Trace out the extent and current of the Luminous and Electrick Effluvia." (G1a:34) On the basis of these two types of experiments, it is possible to construct a reasonably precise description of Gray's concept of electricity.

Gray classified matter as either electric or non-electric. This was accomplished by attempting to electrify the body in question using one of two methods. The first was by rubbing the body with his hand or drawing it through his fingers. This method was particularly suitable for electrifying small bodies, especially cloth. In one series of experiments, G1, Gray claimed to have electrified feathers, hair, silk, linen, wool, paper, leather, wood, parchment, and excut containing gold leaf by this method. Charging matter through friction was rather inconvenient especially for charging large bodies or developing large quantities of charge on bodies. In these cases, Gray would charge the material inductively using a

*In this section, references to Gray's published work will be in the following form, Gm:nn. The Gm refers to the article of that number listed in Appendix 1, and the nn is the page in the manuscript.

previously charged glass tube. Gray detected the presence of the electric effluvia in a body by noting the effect of it upon a crude, brass leaf electrometer. This not only gave Gray an indication of the presence of a charged body, but, by measuring the height to which the leaves rose, he was also able to quantify the attractive force. Gray concluded that "Electrick Bodies" may be animate or inanimate, that the quantity of "Electrick Vertue" which they possessed varied according to their color (G7:170), or temperature (G4:286), but that the virtue was a quality that was inherent (essential) in these bodies. Gray summarized,

...we have now discovered that there is a perpetual attractive Power in all Electrick Bodies, without exciting by either rubbing, heating, etc. or by any other Attrition. (G4:287)

This electric virtue manifested itself by the attraction between bodies which was caused by the action of the electric effluvia

...as all bodies in it see they receive part of the Effluvia of all other bodies that environ them and that the attraction is made according to the current of these Effluvia. (G1a:36)

Although Gray used this attractive force as a measure of the

presence of the effluvia, he was convinced that the attraction was an accident of its presence and not an inherent part of the effluvia. This conclusion was supported by an experiment which Gray performed in 1729 (G2). In this experiment, he suspended two oak cubes, one hollow and the solid. Using a glass tube, Gray electrified the cubes simultaneously by means of a line connected to each of them. He then measured the attractive force exerted on the electrometer he placed under each cube. As the effect on the brass leaves was the same for each cube, Gray concluded that the attractive force exerted by the bodies was equal and that attraction occurred at the surface of bodies and was not proportional to their mass. But the action of the electric effluvia on bodies was not merely a surface effect as would be expected if it acted as a fluid impinging on the surface. Rather, the body was "impregnated with Electrick Effluvia." (G2:31) The attractive effect which manifested itself between the two bodies occurs at the surface, but was a result of "the Electrick Effluvia pass(ing) through all the interior parts of the solid...though no Part but the Surface attracts." (G2:35)

If attraction was a result of the presence of the electric effluvia, then it could be used as a probe of the motion of the effluvia, and, so, armed with his crude electrometer, Gray investigated the transmission of electricity. A number of the experiments in this category

were directed towards determining the extent of transmission. The form of these experiments was always the same (see for example G2:22-31). Gray would suspend some conducting material, electrify one end of it, and measure the effect at the other with the brass leaf electrometer. He conducted these experiments both indoors and out noting the effect of the weather on his results, and often had to redouble his lines of conduction to fit them inside his laboratory. One experiment involved the use of 765 feet of silk line. Gray found that the effluvia could be transmitted over long distances in a number of ways: by direct contact, through wires, rods and threads, through the air and even through a vacuum.

Gray also investigated the directional nature of electrical transmission. In one of these experiments (G5:405-7), he suspended a hoop so that a silk line passed through its center. He electrified the line at one end with a glass rod and found "there was an attractive Influence communicated to the Hoop in all Parts of It." On the basis of these experiments in conduction, Gray decided "that the Elektrik Vertue is carried in several Ways at the Same Time and may be conveyed to considerable Distances."

At this point, Gray's electric effluvia might appear to bear a strong resemblance to the various specific effluvia of the seventeenth century, such as those of Du Hamel or Fomazziri. This resemblance is somewhat misleading

as Gray's effluviu had effects beynd those associated directly with electricity. For instance, the effluviu remained unaffected by a lodestone (G2:32), but was capable of affecting the motion of a compass (G1a:35). Further, it is in these accidental effects of the effluviu that its unifying role in Gray's scientific thought becomes clear. This is somewhat curious since except for three of his last four communications to the Royal Society, the accidental effects occupied an insignificant place in Gray's letters to the Royal Society. Among the effects that first received Gray's attention were the light and noise that result from an electric discharge. In a letter dated January 28, 1735 (G6), Gray described various experiments which produced light as a result of an electric discharge and concluded

...By these experiments we see that an actual Flame of Fire, together with an Explosiön and an Efflutiön of cold water may be produced by Communicative Electricity; and altho' these Effects are at present but in mirius, it is probable, in time there may be found out a way to collect a greater Quantity of it, and consequently to increase the Force of this Electrck Fire, which, by several of these experiments (Silicet nigrus conpense larva) seems to be of the same Nature with that of Thunder and Lightning. (G6:24)

This is the first indication that Gray believed that his electrical effluviu was the cause of other natural

phenomena besides those which were, strictly speaking, electrical. This passage is also interesting because it clearly shows that, as an experimentalist, Gray was keenly aware of the limitations of his equipment, but was nevertheless willing to extrapolate beyond these limitations.

The speculative side of Gray's scientific thought is again evident in his final two papers on electricity, the last one being published posthumously. Both these papers dealt with the mechanical motion which resulted from electrical attraction - which in turn was due to the motion of the electric effluvium. In these two papers, a series of experiments was described involving the motion of spherical bodies around a central, electrified body. Gray made the obvious analogy to motion in the solar system and even referred to the orbiting bodies as "little Planets". At first (G8), Gray was careful to maintain the analogy to planetary motion as merely an analogy. But in the later paper (G9), which was communicated orally to the Secretary of the Royal Society, Cromwell Mortimer, who later transcribed the conversation and published it, the tone was somewhat less cautious. There is the clear impression left that Gray thought that the electric effluvium was responsible for planetary motion. This contrast is evident from the following two passages. From the letter of February 6, 1736

I have lately made several new Experiments upon the projectile and peridulous Motion of small Bodies by Electricity, by which small Bodies may be made to move about larger ones, either in Circles or Ellipses, and that either concentrical or excentrical to the Center of the larger Bodies about which they move so as to make many Revolutions about them; and this Motion will be constantly the same way that the Planets move about the Sun, viz. from the Right to the Left, or from West to East: But these little Planets, if I may so call them, move much faster in their Apogee, than in the Perigee Parts of their Orbits; which is, as you very well know, directly contrary to the Motion of the Planets about the Sun. I have not yet communicated these Experiments to the Royal Society, being in hopes of making some farther Discovery, or at least of shewing them after somewhat more elegant a manner than I make them at present, when you may expect to hear a farther Account of them....(G8:22C)

and from the communication of February 14, 1736

...He told me, he had thought of these Experiments only a short time before his falling sick that he had not tried them with a variety of Bodies, but that from what he had already seen of them, which struck him with new Surprise every Time he repeated them, he hoped, if God would spare his Life but a little longer, he should, from what these Phaenomena point out, bring his Electrical Experiments to the greatest Perfection; and he did not doubt but in a short Time to be able to astonish the world with a new Sort of Planetarium never before thought of and that from these Experiments might be established a certain Theory for accounting for the Motions of the Grand Planetarium of the Universe. (G9:402-3)

On the basis of the latter excerpt, it is possible to organize Gray's published works into a coherent natural philosophy. The early astronomical papers as well as the later electrical ones become in this synthesis investigations into but two of the manifestations of the electric effluvia, and it is the effluvia that is the major cause of action in the universe. It should be emphasized that Gray never published a unified natural philosophy, but it is clear that this was the direction in which his work was heading at the time of his death. Des Cartes' mechanistic universe was never totally accepted, even by Cartesian natural philosophers. Scientists were unwilling to accept a universe made up only of matter. In response to the Cartesian synthesis, Newton proposed that the universe was composed of matter and non-material forces. These forces were themselves explained in terms of the aether, the manifestation of Divine action in the universe. But Newton's natural philosophy was not totally acceptable either. Schofield, as we have noted, maintains that the aether was totally ignored by British natural philosophers in the first half of the 18th century. To say that planetary motion was caused by gravity, was to invite the question, "What is gravity?" Gray felt that a reasonable alternative to gravity, and, ultimately, the aether was an essential but immaterial substance, the electric effluvia.

In contrast to the ether, the electric effluvia could be measured and experimented with, and the occult aspects of it are not nearly as evident. On the other hand, a natural philosophy which contained the electric effluvia as a fundamental cause would avoid the aforementioned philosophical problems of the Cartesian synthesis. Judging by Cromwell Mortimer's reaction in Gray's last article, it would appear that Gray's approach to natural philosophy had some appeal to his contemporaries.

Gray's unfinished natural philosophy also offers some answers to questions raised in the earlier biographical section, particularly with respect to Gray's relationship to Newton. The idea that the electric effluvia is the cause of attraction and repulsion developed slowly in Gray's writings and was preceded by a general dissatisfaction with the Newtonian synthesis. Thus, it was the problem of determining the cause of motion which was the unifying factor in Gray's researches as it was for many natural philosophers of the period. The rejection of the Newtonian synthesis would explain why Gray omitted Newton's name in his list of contributors to the advance of astronomy in the previously mentioned letter to Flamsteed. As time passed, Gray became more convinced that the electric effluvia was the solution to the problem of attraction. This would explain the shift from astronomical to electrical researches. Gray's commitment to the effluviaalist

explanation also provided a substantial basis for disagreement with Newton who, as we have seen, had his own ideas where the unity in nature lay. While direct evidence for conflict on thematic grounds alone is lacking, one can see a profound and fundamental difference in the thought of the two men which might help to account for the antiparallelism of their careers.

V

The preceding analysis makes it clear that Ms. Csler is mistaken in her view that an epistemological change from essentialism to nonessentialism occurred in the seventeenth century. Contrary to her argument, the essentialist effluvial theme persisted throughout the seventeenth and well into the eighteenth century and was fundamental to the natural philosophies of men such as Kepler, Beeckman, Newton, and Gray, as well as providing an explanation for specific natural phenomena as was evidenced by the work of von Guericke and du Hamel.

If the scientific revolution cannot be characterized by the development of nonessentialist natural philosophies, neither can the revolution be viewed solely in terms of effluvia. Rather, the disparities among effluvial explanations, for example those of Gray and Newton, provide the basis for fundamental disagreements between natural philosophers of the period. These differences are in keeping with the very strong thematic component of effluvia, for, the further a proposition is from the contingent plane, the more subject it is to the influence of the various unique factors which effect the thoughts of the individual scientist. Indeed, the variation among effluvial explanations is the most direct indication that a thematic analysis is appropriate. Further, implicit in a thematic approach is the assumption that the presence of one theme

does not necessarily imply the absence of its converse. There is a fundamental difference between thematic and paradigmatic explorations in the history of science. One would therefore expect to see both essentialist and nonessentialist themes in science before, during and after the scientific revolution. The seventeenth century could be seen in terms of the development of essentialist or nonessentialist themes, but the result in either case would be to present an incomplete representation.

Thematic analysis is most useful, however, in assessing the work of an individual, and, aside from any questions concerning essentialism in the 18th century, we have seen this demonstrated most clearly in the investigation of the work of Stephen Gray. The electric effluvia was shown to be both a unifying principle in Gray's thought, and a basis for disagreement between Gray and Newton. With regard to the latter, it is difficult to understand why Schofield classified Gray's work as "Experimental Newtonianism" (1). Further, a thematic analysis of Gray's work belies Cohen's observation that:

Gray was an ingenious and skilled experimenter, but we have no evidence that he created a consistent theory to account for his own discoveries.... (2)

We have traced the development of effluvial

explanations in rather broad outlines and have seen their application in the work of Stephen Gray, but what of the period after Gray's death? Obviously, effluvial explanations persisted, but to trace their further development in any detail would be far beyond the scope of this study. It is possible, however, to make a few observations. References to electric and magnetic virtues continue to appear in the publications of experimenters such as John T. Desaguliers and Charles-Francois Du Fay. Desaguliers' effluvium, however, was corpuscular(3), and, although he was a close associate of Gray(4), Desaguliers placed his electrical experiments within the framework of Newtonian natural philosophy. Thus, his papers on electricity(5) were confined to descriptions of electrical experiments rather than applications of the electrical effluvium to other scientific problems. Du Fay, like Desaguliers, confined his investigations to electrical phenomena, but unlike previous natural philosophers, classified electricity into two types, vitreous and resinous(6). Although he considered the problem of electrical attraction, there is no indication from his papers on electricity(7), that Du Fay considered the wider problem of attraction and repulsion in electrical terms as Gray had. In 1739, Granville Wheeler, an associate of Gray wrote of the electric effluvium,

...yet still, perhaps, it may not be improper for Astronomers to consider whether or no a Medium with this property, that all bodies immersed in it are repulsive of one another, ought not be joined with Gravity to explain heavenly Phenomena...(8)

Despite similarities to earlier effluvia, transition is evident. Explanations which sound effluvial no longer use the term effluvia, but, instead, speak of fluids. In the second Croonian Lecture on Muscular Motion, 1739, one finds the following statements:

There appears to be only four kinds of fluids visible and obvious to the touch, namely water or watery fluids, oil mercury, and fire; the last of which though the most universal and most powerful of all, we are certainly the least acquainted with.(9)

and

Thus, the seemingly contrary or repugnant properties of water and other fluids in cementing and dissolving hardening and softening as well as communicative elasticity to solids are reconciled as arising from the same principle of central attraction producing different and contrary effects by different degrees of force in different proportions of the fluid.(10)

Despite the corpuscular overtones found in these statements,

the fluids to which they refer, especially the fiery fluid, are remarkably similar to effluvia. It would appear as if effluvial ideas began to merge with corpuscular dynamics. The upshot of this union could well have been the various fluid theories of the latter part of the 18th century. But such speculation is perhaps a good basis for further study.

NOTES

Introduction

1. Casler, M. J., ISIS 64, 504-9 (1973).
2. Ibid., p. 509.
3. Ibid., p. 504.
4. Holton, G., Thematic Origins of Scientific Thought, (Cambridge, Harvard University Press, 1974), pp. 55-7.
5. The notion of themata in science has been developed by Gerald Holton in a series of articles, most of which have been collected in Thematic Origins of Scientific Thought. The most recent of Holton's articles on this subject appeared in Science 188, pp. 328-38.

Holton's concept is perhaps best understood through the use of the analogy to three dimensional space. Propositions in science, in so far as they lend themselves to verification, are composed of phenomenic and analytic elements. In the "contingent plane" defined by mathematical and logical statements on one hand and by observables on the other, one finds the realm of public science, i.e. that body of verifiable knowledge which is shared by the scientific community. Orthogonal to this plane, however, is the thematic axis. This is composed of those propositions, either shared or private, which are not subject to verification, but which still influence the development of science. Holton (Science, 1975) separates themata into three categories:

i. Thematic concepts- ideas or aspects of ideas which, while totally unverifiable are important in the direction and definition of a science. Examples of these are the concepts of symmetry and continuity and components of the concepts of force and energy.)

ii. Methodological themata - ideas which provide a basis for the expression and execution of a science. (An example of this type is the idea that scientific results find their best expression in mathematical form.)

iii. Thematic propositions or hypotheses - overarching statements about a science or a part of science.

The thematic component taken together with the contingent plane provide a universe containing all statements of both private and public science.

6. Kuhn, T.S., The Structure of Scientific Revolutions, (Chicago, University of Chicago Press, 1970).
7. Holton, G., Thematic Origins, p. 64.

I

1. Yates, F.A., Giordano Bruno and the Hermetic Tradition, (New York, Vintage Books, 1964) p. 45.
2. Ibid, p. 45.
3. Ibid, p. 2. For a complete discussion of the origins of the various portions of the Hermetic tradition see especially Chapter I.
4. Ibid, pp. 45-6.
5. Gilbert, W., Le Magre, (New York, Basic Books, Inc., 1958), p. 18.
6. Thorndike, L., A History of Magic and Experimental Science, vol. VII, (New York, Macmillan Co. 1929-58), p. 29.
7. Ibid, VII, p. 268.
8. Ibid, VIII, p. 170.
9. Ibid, VII, p. 546
10. Ibid, VII, p. 642.
11. Ibid, VIII, p. 611.
12. Ibid, VII, p. 588.
13. Ibid, VIII, p. 219.

1. Koyre, A., Newtonian Studies, (Chicago, The University of Chicago Press, 1968), p. 65.
2. Ibid., p. 70.
3. Ibid., pp. 108-14.
4. Newton, I., Mathematical Principles of Natural Philosophy, 1729 ed., (Berkeley, University of California Press, 1966), pp. 545-6.
5. Ibid., p. 547.
6. Ibid., p. 302.
7. Ibid., p. 419.
8. Ibid., p. 543.
9. Newton, I., Criticks, 4th ed., (New York, Dover Publications, Inc., 1952), pp. 349-54.
10. Ibid., pp. 262-70.
11. Newton, I., Unpublished Scientific Papers, A. Rupert Hall and Marie Boas Hall, ed. and trans., (Cambridge, Cambridge University Press, 1962), p. 401.
12. Newton, I., Correspondence, vol. II, 1676-1687, H. W. Turnbull, ed., (Cambridge, Cambridge University Press, 1960), pp. 288-95.
13. Newton, Correspondence, vol I, 1661-1675, pp. 362-89.
14. Ibid., pp. 413-5.
15. Newton, Unpublished Papers, pp. 89-156.
16. Ibid., pp. 214-28.
17. Newton, Criticks, p. cxxiii.
18. Newton, Mathematical Principles, p. 547.
19. Newton, Criticks, p. 349.
20. Thorndike, op. cit., VIII, p. 634.
21. Newton, Criticks, p. 352.

22. Schofield, F., Mechanism and Materialism, (Princeton, Princeton University Press, 1970), p. 24.

III

1. Schofield, op. cit., p. 68.
2. This domination was almost total. Early electrical experimenters readily acknowledged their debt to him. For example, Lu Fay began his electrical experiments with a repetition of Gray's work. But, this dominance was due to more than just the preeminence of Gray's electrical experiments, for it appears that he actively discouraged competition. In a letter to the Royal Society published in Phil. Trans., no. 454, 1739, Lesaquiérs prefaces his first published account of his electrical experiments with a reason for the delay in communication to the society which shows this quite clearly. The excuse given was that Lesaquiérs was "unwilling to interfere with the late Mr. Stephen Gray, who had wholly turned his thoughts that way; but was of a temper to give it intirely over, if he imagined that anything was being done in opposition to him."
3. Gray, S., Phil. Trans., vol. 39, no. 444, Nov. and Dec. 1736, item VIII, pp. 400-3.
4. Heilbron, J. L., Dictionary of Scientific Biography, vol. V, Charles C. Gillispie, ed., (New York, Scribner, 1972), pp. 515-7.
5. Chipman, E. A., ISIS 45, pp. 33-40 (1954).
6. Chipman, E. A., ISIS 49, pp. 414-33 (1958).
7. Cohen, I. E., ISIS 45, pp. 41-50 (1954).
8. Heilbron, op. cit., p. 515.
9. Chipman, 49, pp. 429-31.
10. Cohen, 45, pp. 46-7.
11. Chipman, 49, p. 422.
12. Chipman, 45, p. 40.
13. Cohen, 45, p. 46.

14. Chipman, 49, p. 424.
15. Heilbron, op. cit., p. 516.
16. Cohen, 45, pp. 49-50.
17. Chipman, 45, p. 34.
18. Heilbron, op. cit., p. 516.
19. Hauksbee's views on electricity offer a sharp contrast to those of Gray. These views, as well as an account of all Hauksbee's experiments were collected and published by him as Physico-Mechanical Experiments on Various Subjects. In the preface, Hauksbee makes it clear that his study of electrical attraction and repulsion is only a part of the general laws of attraction formulated by Newton (p. A4). Further, he concludes that "the Effluvia, however subtil soever they can be imagin'd to be, are yet Body and Matter and must therefore be liable to the common Laws of Bodies" (p. 56). This corpuscular approach was totally different than that used by Gray and described in the ensuing section. Hauksbee's effluvia was clearly outside the tradition of essentialist effluvia, and, for this reason, has been omitted from the discussion of effluvia in the early 18th century.

V

1. Schofield, op. cit., p. 63.
2. Cohen, I. E., Franklin and Newton, (Baltimore, J. H. Furst Co., 1956), p. 369.
3. J.T. Desaguliers, A Course of Experimental Philosophy, vol. I, (London, 1734), p. 21, and A Course in Experimental Philosophy, (London, 1719) esp. p. 49.
4. A. E. Hall, Dictionary of Scientific Biography, vol. IV, p. 44.
5. Desaguliers' electrical papers may be found in A Course of Experimental Philosophy, vol. II, under the title "A Dissertation concerning Electricity, Written in the Year 1742", (p. 316ff), as well as in the following volumes of the Phil. Trans.:
vol. 41, no. 454, pp. 186-93

"	"	"	"	, pp. 193-99
"	"	"	"	, pp. 200-
"	"	"	"	, pp. 209-10
"	"	"	459,	pp. 634-7
"	"	"	"	, pp. 637-9
"	"	"	"	, pp. 639-40
"	"	"	460,	pp. 661-67
"	42,	"	462,	pp. 14-18

6. C. Du Fay, Phil. Trans., vol. 38, no. 431, pp. 263-4.
7. Du Fay's electrical papers are contained in eight memoirs published in Histoire de l'Académie Royal des Sciences (Paris), (1733 - pp. 23-35, 73-84, 233-54, and 457-76; 1734 - pp. 341-62, and 503-577; 1735 - pp. 86-100, and 307-25). The first series (1733) was summarized by Du Fay and published in Phil. Trans., vol. 38, no. 431, pp. 258-66.
8. Wheeler, G., Phil. Trans., vol 41, p. 124.
9. Croonian lectures on Muscular Motion - 1739, Phil. Trans., vol. 40, p. xix.
10. Ibid, p. xxxvi.

Appendix I

The following is a list of all the work on electricity which Stephen Gray communicated to the Royal Society. Except for the first work, all these letters were published in the Philosophical Transactions of the Royal Society. A complete list of Gray's published works is to be found in I. I. Cohen's article on Gray, ISIS 45, 41-50 (1954). The first letter was included because, although it was not published in Gray's lifetime, it was clearly intended to be so.

- G1a. An Unpublished letter of Stephen Gray on Electrical Experiments, 1707-1708, by F. A. Chipman, ISIS 45, 33-40 (1954).
- G1. An Account of some new Electrical Experiments. By Mr. Stephen Gray. Phil. Trans., vol. 31, no. 366, Sept. - Dec. 1720, item V, pages 104-7.
- G2. A Letter to Cromwell Mortimer, M.D. Secr. R.S. containing several Experiments concerning Electricity; by Mr. Stephen Gray. Phil. Trans., vol. 37, no. 417, Jan. and Feb. 1731, item V, pages 18-44.
- G3. A Letter concerning the Electricity of Water, from Mr. Stephen Gray to Cromwell Mortimer, M.D. Secr. R.S. Phil. Trans., vol. 37, no. 422, Jan. - Mar. 1732, item II, pages 227-30.
- G4. A Letter from Mr. Stephen Gray to Dr. Mortimer, Secr. R.S. containing a farther Account of his Experiments concerning Electricity. Charter - House, June 7th, 1732. Phil. Trans., vol. 37, no. 423, April - June 1732, item IV, pages 285-91.
- G5. Two Letters from Mr. Stephen Gray, F.R.S. to C. Mortimer M.D. Secr. R.S. concerning farther Accounts of his Experiments concerning Electricity. Phil. Trans.,

vol. 37, no. 426, Nov. - Dec. 1732, item I, pages 397-407.

- G6. Experiments and Observations upon the Light that is produced by communicating Electrical Attraction to animal or irritable Bodies, together with some of its most surprizing Effects; communicated in a Letter from Mr. Stephen Gray, F.R.S. to Cromwell Mortimer, M.D., F.R.S. Secr. Phil. Trans., vol. 39, no. 436, Jan - Mar. 1735, item V, pages 16-24.
- G7. A Letter from Stephen Gray, F.R.S. to Dr. Mortimer, Secr. F.R.S. containing some Experiments Relating to Electricity. Phil. Trans., vol. 39, no. 439, Oct. - Dec. 1735, item VI, pages 166-70.
- G8. Mr. Stephen Gray, F.R.S. his last letter to Granville Wheler, Esq., F.R.S. concerning the Revolutions which small pendulous Bodies will, by Electricity, make round larger ones from West to East as Planets do round the Sun. Phil. Trans., vol. 39, no. 441, April - June 1735, item II, page 220.
- G9. An Account of some Electrical Experiments intended to be communicated to the Royal Society by Mr. Stephen Gray, F.R.S. taken from his Mouth by Cromwell Mortimer, M.D. F.R.S. Secr. on Feb. 14, 1735-6, being the Day before he died. Phil. Trans., vol. 39, no. 444, Nov. - Dec. 1736, item VIII, pages 400-3.

Selected Bibliography

I. General

Drake Stillman. Galileo Studies. Ann Arbor: University of Michigan Press, 1970.

Gillispie, Charles C. The Edge of Objectivity. Princeton: Princeton University Press, 1967.

Hall, A. Rupert. The Scientific Revolution 1500-1800. Boston: Beacon Press, 1962.

Holton, Gerald. "On the Role of Themes in Scientific Thought", Science, 188, 328-34 (1975).

Holton, Gerald. Thematic Origins of Scientific Thought. Cambridge: Harvard University Press, 1974.

Kuhn, Thomas S. The Structure of Scientific Revolutions. Chicago: University of Chicago Press, 1974.

Merton, Robert K. "Thematic Analysis in Science: Notes on Holton's Concept", Science 188, 335-6 (1975).

Osler, Margaret J. "Galileo, Motion, and Essences", ISIS 64, 504-9 (1973).

Yates, Frances A. Giordano Bruno and the Hermetic Tradition. New York: Farrar House, 1969.

II. Primary Sources

Desaguliers, John T. A Course in Experimental Philosophy. London, 1719.

Desaguliers, John T. A Course of Experimental Philosophy. vol. I and II. London, 1734 (I) and 1744 (II).

Desaguliers, John T. "Some Thoughts and Experiments concerning Electricity", Phil. Trans., vol. 41, no. 454, 186-93 (1740-1).

Desaguliers, John T. "Experiments made before the Royal Society", Phil. Trans. vol. 41, no. 454, 193-99 (1740-1).

Desaguliers, John T. "An Account of some electrical Experiments made before the Royal Society on Thursday the

16th of February, 1737-8", Phil. Trans., vol. 41, no. 454, 200-8 (1740-1).

Desaqualiers, John T. "An Account of some electrical Experiments made at his Royal Highness the Prince of Wales's House at Cliefden on Thursday the 15th of April 1738 where Electricity was conveyed 420 Feet in a strait line", Phil. Trans., vol. 41, no. 454, 209-10 (1740-1).

Desaqualiers, John T. "Some Things concerning Electricity", Phil. Trans., vol. 41, no. 459, 634-7 (1740-1).

Desaqualiers, John T. "An Account of some Electrical Experiments made before the Royal Society, on Thursday the 22nd of January 1740", Phil. Trans., vol. 41, no. 459, 637-9 (1740-1).

Desaqualiers, John T. "Electrical Experiments made before the Royal Society, on Thursday March 15th 1740-1", Phil. Trans., vol. 41, no. 459, 639-40 (1740-1).

Desaqualiers, John T. "Several Electrical Experiments, made at various Times, before the Royal Society", Phil. Trans., vol. 41, no. 460, 661-7 (1740-1).

Desaqualiers, John T. "Some Further Observations concerning Electricity", Phil. Trans., vol. 42, no. 462, 14-8 (1742-3).

Du Fay, Charles-Francois. "A Letter...to his Grace Charles Duke of Richmond and Lenox, concerning Electricity", Phil. Trans., vol. 38, no. 431, 258-66 (1733-4).

Du Fay, Charles-Francois. "Memoire sur l'Electricite", Histoire de l'Academie Royal des Sciences (Paris), 1733, 23-35, 73-84, 233-54, and 457-76.

Du Fay, Charles-Francois. "Memoire sur l'Electricite", Histoire de l'Academie Royal des Sciences (Paris), 1734, 341-62, and 503-77.

Du Fay, Charles-Francois. "Memoire sur l'Electricite", Histoire de l'Academie Royal des Sciences (Paris), 1735, 86-100, and 307-25.

Gilbert, William. De Magnete. Translated by Silvanus Thompson. New York: Basic Books, 1958.

Gray, Stephen. "An Account of some new Electrical Experiments", Phil. Trans., vol. 31, no. 366, 104-7 (1720).

Gray, Stephen. "A Letter to Cironwell Mortimer, M.D. Secr.

- E.S. containing several Experiments concerning Electricity", Phil. Trans., vol. 37, no. 417, 18-44 (1731).
- Gray, Stephen. "A letter concerning the Electricity of Water", Phil. Trans., vol. 37, no. 422, 227-30 (1732).
- Gray, Stephen. "Two Letters... concerning farther accounts of his experiments concerning Electricity", Phil. Trans., vol. 37, no. 426, 397-407 (1732).
- Gray, Stephen. "Experiments and observations upon the Light that is produced by communicating Electrical Attraction to animal or inanimate Bodies, together with some of its most surprizing Effects", Phil. Trans., vol. 39, no. 436, 16-24 (1735).
- Gray, Stephen. "A Letter... containing some Experiments relative to Electricity", Phil. Trans., vol. 39, no. 439, 166-7 (1735).
- Gray, Stephen. "his last letter.... concerning the Revolutions which small pendulous Bodies will, by Electricity, make round larger ones from West to East as Planets do round the Sun", Phil. Trans., vol. 39, no. 441, 220 (1735).
- Hauksbee, Francis. Physico-Mechanical Experiments on Various Subjects, 2nd edition, 1719. New York: Johnson Reprint Corporation, 1970.
- Mortimer, Cromwell. "An Account of some Electrical Experiments intended to be communicated to the Royal Society by Mr. Stephen Gray, F.R.S., taken from his Mouth ...on Feb. 14, 1735 - being the Day before he died", Phil. Trans., vol. 39, no. 444, 400-3 (1736).
- Newton, Isaac. Correspondence. H. W. Turnbull, editor. Cambridge: Cambridge University Press, 1960.
- Newton, Isaac. Principia vol. I and II, 1729 edition. Translated by Andrew Motte. Berkley: University of California Press, 1966.
- Newton, Isaac. Opticks, 4th edition, 1730. New York: Dover Publications, Inc. 1952.
- Newton, Isaac. Unpublished Scientific Papers. A. R. Hall and Marie Boas Hall, editors and translators. Cambridge: Cambridge University Press, 1962.

III. Secondary Sources

- Chipman, Robert A. "An Unpublished Letter of Stephen Gray on Electrical Experiments, 1707-1708", ISIS, 45, 33-40 (1954).
- Chipman, Robert A. "The Manuscript Letters of Stephen Gray, F.R.S. (1666/7-1736)", ISIS, 49, 414-33 (1958).
- Cohen, I. Bernard. "Neglected Sources for the Life of Stephen Gray", ISIS, 45, 41-50 (1954).
- Cohen, I. Bernard. Franklin and Newton. Philadelphia: The American Philosophical Society, 1958.
- Gillispie, Charles C., editor. Dictionary of Scientific Biography. New York: Scribner, 1972.
- Hall, Marie Boas and Hall, A. Rupert. "Newton's Electrical Spirit: Four Oddities", ISIS, 50, 473-6 (1959).
- Hall, A. Rupert and Hall, Marie Boas. "Newton's Theory of Matter", ISIS, 51, 131-44 (1960).
- Heimann, F. E. and McGuire, J. E. "Newtonian Forces and Lockean Powers: Concepts of Matter in Eighteenth-Century Thought", Historical Studies in the Physical Sciences, 3, 233-306 (1971).
- Koyre, Alexandre. From Closed World to the Infinite Universe. Baltimore: The Johns Hopkins Press, 1970.
- Koyre, Alexandre. Newtonian Studies. Chicago: The University of Chicago Press, 1965.
- Manuel, Frank. A Portrait of Isaac Newton. Cambridge: The Harvard University Press, 1968.
- Schofield, Robert E. Mechanism and Materialism. Princeton: Princeton University Press, 1970.
- Thorndike, Lynn. A History of Magic and Experimental Science. New York: Macmillan Co., 1929-58.