

CONTRIBUTIONS FROM
THE MUSEUM OF HISTORY AND TECHNOLOGY:

PAPER 8

THE NATURAL PHILOSOPHY OF
WILLIAM GILBERT AND HIS PREDECESSORS

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Until several decades ago, the physical sciences were considered to have had their origins in the 17th century—mechanics beginning with men like Galileo Galilei and magnetism with men like the Elizabethan physician and scientist William Gilbert.

Historians of science, however, have traced many of the 17th century's concepts of mechanics back into the Middle Ages. Here, Gilbert's explanation of the loadstone and its powers is compared with explanations to be found in the Middle Ages and earlier.

From this comparison it appears that Gilbert can best be understood by considering him not so much a herald of the new science as a modifier of the old.

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THE YEAR 1600 SAW the publication by an English physician, William Gilbert, of a book on the loadstone. Entitled *De magnete*,¹ it has traditionally been credited with laying a foundation for the modern science of electricity and magnetism. The following essay is an attempt to examine the basis

¹ William Gilbert, *De magnete, magneticisque corporibus et de magno wignete tellure; physiologia nova, plurimis & argumentis, & experimentis, demonstrata*, London, 1600, 240 pp., with an introduction by Edward Wright. All references to Gilbert in this article, unless otherwise noted, are to the American translation by P. Fleury Mottelay, 368 pp., published in New York in 1893, and are designated by the letter M. However, the Latin text of the 1600 edition has been quoted wherever I have disagreed with the Mottelay translation.

A good source of information on Gilbert is Dr. Duane H. D. Roller's doctoral thesis, written under the direction of Dr. I. B. Cohen of Harvard University. Dr. Roller, at present Curator of the De Golyer Collection at the University of Oklahoma, informed me that an expanded version of his dissertation will shortly appear in book form. Unfortunately his researches were not known to me until after this article was completed.

for such a tradition by determining what Gilbert's original contributions to these sciences were, and to make explicit the sense in which he may be considered as being dependent upon earlier work. In this manner a more accurate estimate of his position in the history of science may be made.

One criterion as to the book's significance in the history of science can be applied almost immediately. A number of historians have pointed to the introduction of numbers and geometry as marking a watershed between the modern and the medieval understanding of nature. Thus A. Koyré considers the Archimedeanization of space as one of the necessary features of the development of modern astronomy and physics.² A. N. Whitehead and E. Cassirer have turned to measurement and the quantification of force as marking this transition.³ However, the

² Alexandre Koyré, *Études galiléennes*, Paris, 1939

³ Alfred N. Whitehead, *Science and the modern world*, New York, 1925, ch. 3; Ernst Cassirer, *Das Erkenntnisproblem*, ed. 3, Berlin, 1922, vol. 1, pp. 314-318, 352-359.

G V I L I E L M I G I L
B E R T I C O L C E S T R E N
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D E M A G N E T E , M A G N E T I
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L O N D I N I E

E X C V D E B A T P E T R V S S H O R T A N N O
M D C .

Figure 1.—WILLIAM GILBERT'S BOOK ON THE LOADSTONE. TITLE PAGE OF THE FIRST EDITION.
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obvious absence⁴ of such techniques in *De magnete* makes it difficult to consider Gilbert as a founder of modern electricity and magnetism in this sense.

There is another sense in which it is possible to contend that Gilbert's treatise introduced modern studies in these fields. He has frequently been credited with the introduction of the inductive method based upon stubborn facts, in contrast to the methods and content of medieval Aristotelianism.⁵ No science can be based upon faulty observations and certainly much of *De magnete* was devoted to the destruction of the fantastic tales and occult sympathies of the Romans, the medieval writers, and the Renaissance. However, let us also remember that Gilbert added few novel empirical facts of a fundamental nature to previous observations on the loadstone. Gilbert's experimental work was in large part an expansion of Petrus Peregrinus' *De magnete* of 1269,⁶ and a development of works like Robert Norman's *The new attractive*,⁷ in which the author discussed how one could show experimentally the declination and inclination of a magnetized needle, and like William Borough's *Discourse on the variation of the compass or magnetized needle*,⁸ in which the author suggested the use of magnetic declination and inclination for navigational purposes but felt too little was known about it. That other sea-going nations had been considering

⁴ However, see M: pp. 161, 162, 168, 335.

⁵ For example, William Whewell, *History of the inductive sciences*, ed. 3, New York, 1858, vol. 2, pp. 192 and 217; Charles Singer, *A short history of science to the nineteenth century*, Oxford, 1943, pp. 188 and 343; and A. R. Hall, *The scientific revolution*, Boston, 1956, p. 185.

⁶ *Petri Peregrini maricurtensis, de magnete, seu rota perpetui motus, libellus*, a reprint of the 1558 Angsburg edition in J. G. G. Hellmann, *Rara magnetica*, Berlin, 1898, not paginated. A number of editions of Peregrinus' work, both ascribed to him and plagiarized from him, appeared in the 16th century (see Heinz Balmer, *Beiträge zur Geschichte der Erkenntnis des Erdmagnetismus*, Aarau, 1956, pp. 249–255).

⁷ Hellmann, *ibid.*, Robert Norman, *The newe attractive, containing a short discourse of the magnes or lodestone, and amongst other his vertues, of a newe discovered secret and subtill propertie, concerning the declining of the needle, touched therewith under the plaine of the horizon. Now first founde out by Robert Norman Hydrographer*. London, 1581. The possibility is present that Norman's work was a direct stimulus to Gilbert, for Wright's introduction to *De magnete* stated that Gilbert started his study of magnetism the year following the publication of Norman's book.

⁸ Hellman, *ibid.*, William Borough, *A discourse of the variation of the compasse, or magneticall needle. Wherein is mathematically shewed, the manner of the observation, effects, and application thereof, made by W. B. And is to be annexed to the newe attractive of R. N.* London, 1596.

using the properties of the magnetic compass to solve their problems of navigation in the same manner can be seen from Simon Stevin's *De havenvinding*.⁹

Instead of new experimental information, Gilbert's major contribution to natural philosophy was that revealed in the title of his book—a new philosophy of nature, or physiology, as he called it, after the early Greeks. Gilbert's attempt to organize the mass of empirical information and speculation that came from scholars and artisans, from chart and instrument makers, made him “the father of the magnetic Philosophy.”¹⁰

Gilbert's *De magnete* was not the first attempt to determine the nature of the loadstone and to explain how it could influence other loadstones or iron. It is typical of Greek philosophy that one of the first references we have to the loadstone is not to its properties but to the problem of how to explain these properties. Aristotle¹¹ preserved the solution of the first of the Ionian physiologists: “Thales too . . . seems to suppose that the soul is in a sense the cause of movement, since he says that a stone has a soul because it causes movement to iron.” Plato turned to a similar animistic explanation in his dialogue, *Ion*.¹² Such an animistic solution pervaded many of the later explanations.

That a mechanical explanation is also possible was shown by Plato in his *Timaeus*.¹³ He argued that since a vacuum does not exist, there must be a plenum throughout all space. Motion of this plenum can carry objects along with it, and one could in this manner explain attractions like that due to amber and the loadstone.

Another mechanical explanation was based upon a postulated tendency of atoms to move into a vacuum rather than upon the latter's non-existence. Lucretius restated this Epicurean explanation in his

⁹ Hellman, *ibid.*, Simon Stevin, *De havenvinding*, Leyden, 1599. It is interesting to note that Wright translated Stevin's work into English.

¹⁰ As Edward Wright was to call him in his introduction.

¹¹ Aristotle, *On the soul*, translated by W. S. Hett, Loeb Classical Library, London, 1935, 405a20 (see also 411a8: “Some think that the soul pervades the whole universe, whence perhaps came Thales' view that everything is full of gods”).

¹² Plato, *Ion*, translated by W. R. M. Lamb, Loeb Classical Library, London, 1925, 533 (see also 536).

¹³ Plato, *Timaeus*, translated by R. G. Bury, Loeb Classical Library, London, 1929, 80. It is difficult to determine which explanation Plato preferred, for in both cases the speaker may be only a foil for Plato's opinion rather than an expression of these opinions.

De rerum natura.¹⁴ Atoms from the loadstone push away the air and tend to cause a vacuum to form outside the loadstone. The structure of iron is such that it, unlike other materials, can be pushed into this empty space by the thronging atoms of air beyond it.

Galen¹⁵ returned to a quasi-animistic solution in his denial of Epicurus' argument, which he stated somewhat differently from Lucretius. One can infer that Galen held that all things have, to a greater or lesser degree, a sympathetic faculty of attracting its specific, or proper, quality to itself.¹⁶ The loadstone is only an inanimate example of what one finds in nutritive organs in organic beings.

One of the few writers whose explanations of the loadstone Gilbert mentioned with approval is St. Thomas Aquinas. Although the medieval scholastic philosophy of St. Thomas seems foreign to our way of thinking, it formed a background to many of Gilbert's concepts, as well as to those of his predecessors, and it will assist our discussion to consider briefly Thomist philosophy and to make its terminology explicit at this point.¹⁷

In scholastic philosophy, all beings and substances are a coalescence of inchoate matter and enacting form. Form is that which gives being to matter and which is responsible for the "virtus" or power to cause change, since matter in itself is inert. Moreover, forms can be grasped intellectually, whence the nature of a being or a substance can be known. Any explanation of phenomena has to be based upon these innate natures, for only if the nature of a substance is known can its properties be understood. Inanimate natures are determined by observation, abstraction, and induction, or by classification.¹⁸

The nature of a substance is causally prior to its properties; while the definition of the nature is logically prior to these properties. Thus, what we call

¹⁴ Lucretius, *De rerum natura*, translated by W. H. D. Rouse, Loeb Classical Library, London, 1924, bk. VI, lines 998-1041.

¹⁵ Galen, *On the natural faculties*, translated by A. S. Brock, Loeb Classical Library, London, 1916, bk. 1 and bk. 3. A view similar to this appeared in Plato, *Timaeus*, 81 (see footnote 13).

¹⁶ This same concept was to reappear in the Middle Ages as the *inclinatio ad simile*.

¹⁷ The background for much of the following was derived from Annaliese Maier, *An der Grenze von Scholastik und Naturwissenschaft*, ed. 2, Rome, 1952.

¹⁸ St. Thomas' epistemology for the natural inanimate world was based upon Aristotle's dictum: that which is in the mind was in the senses first.

the theory of a substance is expressed in its definition, and its properties can be deduced from this definition.

The world of St. Thomas is not a static one, but one of the Aristotelian motions of quantity (change of size), of quality (alteration), and of place (locomotion). Another kind of change is that of substance, called generation and corruption, but this is a mutation, occurring instantly, rather than a motion, that requires time. In mutation the essential nature is replaced by a new substantial form.

All these changes are motivated by a causal hierarchy that extends from the First Cause, the "Dator Formarum," or Creator, to separate intellectual substances that may be angels or demons, to the celestial bodies that are the "generantia" of the substantial forms of the elements and finally to the four prime qualities (dry and wet, hot and cold) of the substantial forms. Accidental forms are motivated by the substantial forms through the instrumentality of the four prime qualities, which can only act by material contact.

The only causal agents in this hierarchy that are learned through the senses are the tangible qualities. Usually the prime qualities are not observed directly, but only other qualities compounded of them. One of the problems of scholastic philosophy was the incorporation, into this system of efficient agents, of other qualities, such as the qualities of gravity and levity that are responsible for upward and downward motion.

Besides the causal hierarchy of forms, the natural world of St. Thomas existed in a substantial and spatial hierarchy. All substances whether an element or a mixture of elements have a place in this hierarchy by virtue of their nature. If the material were removed from its proper place, it would tend to return. In this manner is obtained the natural downward motion of earth and the natural upward motion of fire.

Local motion can also be caused by the "virtus coeli" generating a new form, or through the qualitative change of alteration. Since each element and mixture has its own natural place in the hierarchy of material substances, and this place is determined by its nature, changes of nature due to a change of the form can produce local motion. If before change the substance is in its natural place, it need not be afterwards, and if not, would then tend to move to its new natural place.

It will be noted that the scholastic explanation of

inanimate motion involved the action and passion of an active external mover and a passive capacity to be moved. Whence the definition of motion that Descartes¹⁹ was later to deride, "motus est actus entis in potentia prout quod in potentia."

We have seen above that the "motor essentialis" for terrestrial change is the "virtus coeli." Thus the enacting source of all motion and change is the heavens and the heavenly powers, while the earth and its inhabitants becomes the focus or passive recipient of these actions. In this manner the scholastic restated in philosophical terms the drama of an earth-centered universe.

Although change or motion is normally effected through the above mentioned causal hierarchy, it is not always necessary that actualization pass from the First Cause down through each step of the hierarchy to terminate in the qualities of the individual being. Some of the steps could be by-passed; for instance man's body is under the direct influence of the celestial bodies, his intellect under that of the angels and his will under God.²⁰ Another example of effects not produced through the tangible prime qualities is that of the tide-producing influence of the moon on the waters of the ocean or the powers of the loadstone over iron. Such causal relations, where some members of the normal causal chain have been circumvented, are called occult.²¹

While St. Thomas referred to the loadstone in a number of places as something whose nature and occult properties are well known, it was always as an example or as a tangential reference. One does not find a systematic treatment of the loadstone in St. Thomas, but there are enough references to

provide a fairly explicit statement of what he considered to be the nature of the magnet.

In one of his earliest writings, St. Thomas argued that the magnet attracts iron because this is a necessary consequence of its nature.²²

Respondeo dicendum, quod omnibus rebus naturaliter insunt quaedam principia, quibus non solum operationes proprias efficere possunt, sed quibus etiam eas convenientes fini suo reddant, sive sint actiones quae consequantur rem aliquam ex natura sui generis, sive consequantur ex natura speciei, ut magneti competit ferri deorsum ex natura sui generis, et attrahere ferrum ex natura speciei. Sicut autem in rebus agentibus ex necessitate naturae sunt principia actionum ipsae formae, a quibus operationes proprie prodeunt convenientes fini. . . .

Due to its generic form, the loadstone is subject to natural motion of place of up and down. However, the "virtus" of its specific form enabled it to produce another kind of motion—it could draw iron to itself.

Normally the "virtus" of a substance is limited to those contact effects that could be produced by the form operating through the active qualities of one substance, on the relatively passive qualities of another. St. Thomas asserted the loadstone to be one of these minerals, the occult powers of whose form goes beyond those of the prime qualities.²³

Forma enim elementi non habet aliquam operationem nisi quae fit per qualitates activas et passivas, quae sunt dispositiones materiae corporalis. Forma autem corporis mineralis habet aliquam operationem excedentem qualitates activas et passivas, quae consequitur speciem ex influenza corporis coelestis, ut quod magnes attrahit ferrum, et quod saphirus curat apostema.

That this occult power of the loadstone is a result of the direct influence of the "virtus coeli" was

¹⁹ René Descartes, *Oeuvres*, Charles Adam and Paul Tannery, Paris, 1897–1910, vol. 2, p. 597 (letter to Mersenne, 16 Oct., 1639), and vol. 11 (*Le Monde*), p. 39. The original definition can be found in Aristotle, *Physics*, translated by P. H. Wickstead and F. M. Cornford, Loeb Classical Library, London, 1934, 201a10. Aquinas rephrases the definition as "Motus est actus existentis in potentia secundum quod huius modi." See St. Thomas Aquinas, *Opera omnia*, Antwerp, 1612, vol. 2, *Physicorum Aristotelis expositio*, lib. 3, lect. 2, cap. a, p. 29.

²⁰ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 9, *Summa contra gentiles*, lib. 3, cap. 92 (Quo modo dicitur aliquis bene fortunatus et quo modo adjuvatur homo ex superioribus causis), p. 343.

²¹ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 17 *Opuscula, De operationibus occultis naturae ad quendam militem ultramontem*, pp. 213–224

²² St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 7, *Scriptum in quantum librum sententiarum magistri Petri Lombardi*, lib. 4, disq. 33 (*De diversis coniugii legibus*), art. 1 (Utrum habere plures uxores sit contra legem naturae), p. 168. The same statement occurs in one of his most mature works, *op. cit.* vol. 20, *Summa theologica*, pars 3 (supplementum), quaestio 65 (*De pluralitate uxorum in quinque articulos divisa*), art. 1 (Utrum habere plures uxores sit contra legem naturae), p. 107.

²³ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 8, *Quaestio unica: de spiritalibus creaturis*, art. 2 (Utrum substantia spiritalis possit uniri corpori), p. 404. See also vol. 9, *Summa contra gentiles*, lib. 3, cap. 92 (Quomodo dicitur aliquis bene fortunatus, et quomodo adjuvatur homo ex superioribus causis), p. 344; and vol. 17, *Opuscula, De operationibus occultis naturae ad quendam militem ultramontem*, pp. 213–214.

expounded at greater length in his treatise on the soul.²⁴

Quod quidem ex propriis formarum operationibus perpendi potest. Formae enim elementorum, quae sint infimae et materiae propinquissime, non habent aliquam operationem excedentem qualitates activas et passivas, ut rarum et densum, et aliae huiusmodi, qui videntur esse materiae dispositiones. Super has autem sunt formae mistorum quae praeter praedictas operationes, habent aliquam operationem consequentem speciem, quam fortiantur ex corporibus coelestibus; sicut quod magnes attrahit ferrum non propter calorem aut frigiditatem, aut aliquid huiusmodi; sed ex quadam participatione virtutis coelestis. Super has autem formas sint iterum animae plantarum, quae habent similitudinem non solum ad ipsa corpora coelestia, sed ad motores corporum coelestium, in quantum sunt principia cuiusdam motus, quibusdam seipsa moventibus. Super has autem ulterius sunt animae brutorum, quae similitudinem iam habent ad substantiam moventem coelestia corpora, non solum in operatione qua movent corpora, sed etiam in hoc quod in seipsis cognoscitivae sunt, licet brutorum cognitio sit materialium tantum et materialiter. . . .

St. Thomas placed the form of the magnet and its powers in the hierarchy of forms intermediate between the forms of the inanimate world and the forms of the organic world with its hierarchy of plant, animal and rational souls. The form of the loadstone is then superior to that of iron, which can only act through its active and passive qualities, but inferior to the plant soul, that has the powers of growth from the "virtus coeli." This is similar to Galen's comparison of the magnet's powers to that of the nutritive powers of organic bodies.

In his commentary on Aristotle's *Physics*, St. Thomas explained how iron is moved to the magnet. It is moved by some quality imparted to the iron by the magnet.²⁵

Illud ergo trahere dicitur, quod movet alterum ad seipsum. Movere autem aliquid secundum locum ad seipsum contingit tripliciter. Uno modo sicut finis movet; unde et finis dicitur trahere, secundum illud poctate: "trahit sua quemque voluptas"; et hoc modo potest dici quod

²⁴ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 8, *Quaestio unvca: de anima*, art. 1 (Utrum anima humana possit esse forma et hoc aliquid), p. 437. See also vol. 8, *Quaestio: De veritate*, quaestio 5 (De providentia), art. 10 (Utrum humani actus a divina providentia gubernentur mediis corporibus coelestibus), p. 678.

²⁵ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 2, *Physicorum Aristotelis expositio*, lib. 7, lect. 3, cap. g (Probatur in motu locali quod movens et motum oportet esse simul), p. 97 (quoted in Gilbert, M: p. 104).

locus trahit id, quod naturaliter movetur ad locum. Alio modo potest dici aliquid trahere, quia movet illud ad seipsum alterando aliquo modo, ex qua alteratione contingit quod alteratum moveatur secundum locum: et hoc modo magnes dicitur trahere ferrum. Sicut enim generans movet gravia et levia, in quantum dat eis formarum per quam moventur ad locum, ita et magnes dat aliquam qualitatem ferro, per quam movetur ad ipsum. Et quod hoc sit verum patet ex tribus. Primo quidem quia magnes non trahit ferrum ex quacumque distantia, sed ex propinquo; si autem ferrum moveretur ad magnetem solum sicut ad finem, sicut grave ad suum locum, ex qualibet distantia tenderet ad ipsum. Secundo, quia, si magnes aliis perungatur, ferrum attrahere non potest; quasi aliis vim alterativam ipsius impediens, aut etiam in contrarium alterantibus. Tertio, quia ad hoc quod magnes attrahat ferrum, oportet prius ferrum liniri cum magnete, maxime si magnes sit parvus; quasi ex magnete aliquam virtutem ferrum accipiat ut ad eum moveatur. Sic igitur magnes attrahit ferrum non solum sicut finis, sed etiam sicut movens et alterans. Tertio modo dicitur aliquid attrahere, quia movet ad seipsum motu locali tantum. Et sic definitur hic tractio, prout unum corpus trahit alterum, ita quod trahens simul moveatur cum eo quod trahitur.

As the "generans" of terrestrial change moves what is light and heavy to another place by implanting a new form in a substance, so the magnet moves the iron by impressing upon it the quality by which it is moved. By virtue of the new quality, the iron is not in its natural place and moves accordingly. St. Thomas proved that the loadstone acts as a secondary "generans" in three ways: (1) the loadstone produces an effect not from any distance but only from a nearby position (showing that this motion is due to more than place alone), (2) rubbing the loadstone with garlic acts as if it impedes or alters the "virtus magnetis," and (3) the iron must be properly aligned with respect to the loadstone in order to be moved, especially if the loadstone is small. Thus the iron is moved by the magnet not only to a place, but also by changing and altering it; one has not only the change of locomotion but that of alteration. Moreover the source of this alteration in the iron is not the heavens but the loadstone. Accordingly the loadstone could cause change in another substance because it could influence the nature of the other substance.

About the time that St. Thomas was writing his letter *De operationibus occultis naturae* to a certain knight, Petrus Peregrinus was writing from a military camp a letter in which he showed how certain relatively new effects could be produced by the loadstone.

He was more interested in what he could do with the magnet than in explaining these effects. However, he discussed it at sufficient length for one to find that his explanation of magnetic phenomena was basically similar to that of his contemporary, St. Thomas.

Peregrinus based his discussion of the loadstone upon its nature and analyzed magnetic phenomena in terms of the change of alteration. In magnetic attraction, the nature of the iron is altered by having a new quality impressed upon it,²⁶ and the loadstone is the agent that makes the iron the same species as the stone.²⁷

. . . Oportet enim quod illud quod iam conversum est ex duobus in unum, sit in eadem specie cum agente; quod non esset, si natura istud impossibile eligeret.

This impressed similarity to the agent, Peregrinus realized, is not a pole of the same polarity but one opposite to that of the inducing pole. To produce this effect, the virtue of the stronger agent dominates the weaker patient and impresses the virtue of the stronger on the weaker so that they are made similar.²⁸

. . . In cuius attractione, lapis fortioris virtutis agens est; debilioris vero patiens.

A further instance of alteration occurs in the reversal of polarity of magnetized iron when one brings two similar poles together. Again, the stronger agent dominates the weaker patient and the iron is left with a similarity to the last agent.²⁹

. . . Causa huius est impressio ultimi agentis, confudentis et alterantis virtutem primi.

In this assimilation of the agent to the patient, another effect is produced: the agent not only desires to assimilate the patient to itself, but to unite with it to become one and the same. Speaking of the motion to come together, he says:³⁰

Huius autem rei causam per hanc viam fieri existimo: agens enim intendit suum patiens non solum sibi assimilare, sed unire, ut ex agente et patiente fiat unum, per numerum. Et hoc potes experiri in isto lapide mirabili in hunc modum. . . . Agens ergo, ut vides experimento, intendit suum paciens sibi unire; hoc autem fit ratione similitudinis inter ea.

²⁶ Hellmann, *op. cit.* (footnote 6), Peregrinus, pt. 1, ch. 8. The magnet attracts the iron "secundum naturalem appetitum lapidis . . . sine resistentia." There is no natural resistance to this motion since it is no longer contrary to the nature of the iron. The nature of the iron has changed.

²⁷ *Ibid.*, pt. 1, ch. 9.

²⁸ *Ibid.*, pt. 1, ch. 9.

²⁹ *Ibid.*, pt. 1, ch. 8.

³⁰ *Ibid.*, pt. 1, ch. 9.

Oportet ergo . . . virtute attractionis, fiat una linea, ex agente et patiente, secundum hunc ordinem . . .

The nature of the magnet, as an active cause, tends to enact, and since it acts in the best manner in which it is able, it acts so as to preserve the similarities of opposite poles.³¹

Natura autem, que tendet ad esse, agit meliori modo quo potest, eligit primum ordinem actionis, in quo melius salvatur idemptitas, quam in secundo . . .

Thus unlike poles tend to come together when a dissected magnet is reassembled.

Like St. Thomas, Peregrinus argued that the magnet receives its powers from the heavens. But he further specified this by declaring that different virtues from the different parts of the heavens flow into their counterpart in the loadstone—from the poles of the heavens the virtue flows into the poles of the magnet.³²

Practerea cum ferrum, vel lapis, vertatur tam ad partem meridionalem quam ad partem septentrionalem . . . existima cogimur, non solum a partem septentrionali, verum etiam a meridionali virtutem influere in polos lapidis, magis quam a locis minere . . . Omnes autem orbis meridiani in polis mundi concurrunt; quare, a polis mundi, poli magnetis virtutem recipiunt. Et ex hoc apparet manifeste quod non ad stellam nauticam movetur, cum ibi non concurrant orbis meridiani, sed in polis; stella enim nautica, extra orbem meridianum cuiuslibet regionis semper invenitur, nisi bis, in completa firmanenti revolutione. Ex hiis ergo manifestum est quod a partibus celi, partes magnetis virtutem recipiunt.

and similarly for the other parts of the heavens and the other parts of the loadstone.³³

Ceteras autem partes lapidis merito estimare potes, influentiam a reliquis celi partibus retinere, ut non sic solum polos lapidis a polis mundi, sed totum lapidem a toto celo, recipere influentiam et virtutem, estimates.

Physical proof for such influences was adduced by Peregrinus from the motions of the loadstone. That the poles of the loadstone receive their virtue from the poles of the heavens follows experimentally from north-south alignment of a loadstone. That not only the poles but the entire loadstone receives power from corresponding portions of the heavens follows from the fact that a spherical loadstone, when "properly balanced," would follow the motion of the heavens.³⁴

³¹ *Ibid.*, pt. 1, ch. 9. See also footnote 27.

³² *Ibid.*, pt. 1, ch. 10. See also ch. 4.

³³ *Ibid.*, pt. 1, ch. 10. See also ch. 4.

³⁴ *Ibid.*, pt. 1, ch. 10.

Quod tibi tali modo consulo experire: . . . Et si tunc lapis moveatur secundum celi motum, gaudeas te esse assecutum secretum mirabile; si vero non, imperitie tue, potiusquam nature, defectus imputetur. In hoc autem situ, seu modo positionis, virtutes lapidis huius estimo conservari proprie, et in reliquis sitibus celi virtutem eius obsecari, seu ebetari, potiusquam conservari puto. Per hoc autem instrumentum excusaberis ab omni horologio; nam per ipsum scire poteris Ascensus in quacunque hora volueris, et omnes alias celi dispositiones, quas querunt Astrologi.

As the heavens move eternally, so the spherical loadstone must be a "perpetuum mobile".

Another of the scholars whose explanation of the loadstone Gilbert noted with approval was Cardinal Nicholas of Cusa.³⁵ The latter's references to it were not as direct as those of St. Thomas, but he did use it as an image several times to provide a microcosmic example of the relation of God to his creation. From this one can infer that he explained the preternatural motion of the magnet and the iron by impressed qualities, the heavens being the agent for the loadstone, and the loadstone, the agent for iron.

In the *Idiota de sapientia* the Cardinal used the image of the magnet and the iron to provide a concrete instance of his "coincidentia oppositorum," to illustrate how eternal wisdom, in the Neoplatonic sense, could, at the same time, be principle or cause of being, its complement and also its goal.³⁶

Si igitur in omni desiderio vitae intellectualis attenderes, a quo est intellectus, per quod movetur et ad quod, in te comperires dulcedinem sapientiae aeternae illam esse, quae tibi facit desiderium tuum ita dulce et delectabile, ut in inerrabili affectu feraris ad eius comprehensionem tanquam ad immortalitatem vitae tue, quasi ad ferrum et magnetem attendas. Habet enim ferrum in magnete quoddam sui effluxus principium; et dum magnes per sui praesentiam excitat ferrum grave et ponderosum, ferrum mirabili desiderio fertur etiam supra motum naturae, quo secundum gravitatem deorsum tendere debet, et sursum movetur se in suo principio uniendo. Nisi enim in ferro esset quaedam praegustatio naturalis ipsius magnetis, non moveretur plus ad magnetem quam ad alium lapidem; et

nisi in lapide esset major inclinatio ad ferrum quam cuprum, non esset illa attractio. Habet igitur spiritus noster intellectualis ab aeterna sapientia principium sic intellectualiter essendi, quod esse est conformius sapientiae quam aliud non intellectuale. Hinc irradiatio seu immissio in sanctam animam est motus desideriosus in excitatione.

By virtue of the principle that flows from the magnet to the iron—which principle is potentially in the iron, for the iron already has a foretaste for it—the excited iron could transcend its gravid nature and be preternaturally moved to unite with its principle. Reciprocally, the loadstone has a greater attraction to the iron than to other things. Just as the power of attraction comes from the loadstone, so the Deity is the source of our life. Just as the principle implanted in the magnet moves the iron against its heavy nature, so the Deity raises us above our brutish nature so that we may fulfill our life. As the iron moves to the loadstone, so we move to the Deity as to the goal and end of our life.

In *De pace fidei*, Cusa³⁷ again used the iron and magnet as an example of motion contrary to and transcending nature. He explained this supernatural motion as being due to the similarity between the nature of the iron and the magnet, and this in turn is analogous to the similarity between human spiritual nature and divine spiritual nature. As the iron can move upward to the loadstone because both have similar natures, so man can transcend his own nature and move towards God when his potential similitude to God is realized. Another image used by Cusa was the comparison of Christ to the magnetic needle that takes its power from the heavens and shows man his way.³⁸

The Elizabethan Englishman Robert Norman also turned to the Deity to explain the wonderful effects of the loadstone.³⁹

Now therefore . . . divers have whetted their wits, yea, and dulled them, as I have mine, and yet in the end have been constrained to fly to the cornerstone: I mean God: who . . . hath given Virtue and power to this Stone

³⁵ However, he may not always have approved of him. See M:74; "Overinquisitive theologians, too, seek to light up God's mysteries and things beyond man's understanding by means of the loadstone and amber."

³⁶ Nicholas of Cusa (Nicolaus Cusanus), *Nicolaus von Cues, Texte seiner philosophischen Schriften*, ed. A. Petzelt, Stuttgart, 1949, bk. 1, *Idiota de sapientia*, p. 306 (quoted in Gilbert, M:104). It is interesting that Cusa held that the loadstone has an inclination to iron, as well as the converse!

³⁷ Cusa, *Cusa Schriften*, vol. 8, *De pace fidei*, translated by L. Mohler, Leipzig, 1943, ch. 12, p. 127.

³⁸ Cusa, *Exercitationes*, ch. 7, 563 and 566, quoted in, F. A. Scharpff, *Des Cardinals und Bischofs Nicolaus Von Cusa Wichtigste Schriften in Deutscher Uebersetzung*, Freiburg, 1862, p. 435. See also Martin Billinger, *Das Philosophische in Den Exatationen Des Nicolaus Von Cues*, Heidelberg, 1938, and *Cusa Schriften* (see footnote 37), vol. 8, p. 209, note 105. Gilbert (M: p. 223) called the compass "the finger of God."

³⁹ Hellmann, *op. cit.* (footnote 6), Norman, bk. 1, ch. 8.

. . . to show one certain point, by his own nature and appetite . . . and by the same vertue, the Needle is turned upon his own Center, I mean the Center of his Circular and invisible Vertue . . . And surely I am of opinion, that if this would be found in a Sphericall form, extending round about the Stone in Great Compass, and the dead body Stone in the middle therof: Whose center is the center of his aforesaid Vertue. And this I have partly proved, and made visible to be seen in the same manner, and God sparing me life, I will herein make further Experience.

Again, one can infer that the heavens impart a guiding principle to the iron which acts under the influence of this Superior Cause.

One of the points made in St. Thomas' argument on motion due to the loadstone was that there is a limit to the "virtus" of the loadstone, but he did not specify the nature of it. Norman refined the Thomist concept of a bound by making it spherical in form, foreshadowing Gilbert's "orbis virtutis."

Gilbert's philosophy of nature does not move far from scholastic philosophy, except away from it in logical consistency. As the concern of Aristotle and of St. Thomas was to understand being and change by determining the nature of things, so Gilbert sought to write a logos of the physis, or nature, of the loadstone—a physiology.⁴⁰ This physiology was not formally arranged into definitions obtained by induction from experience, but nevertheless there was the same search for the quiddity of the loadstone. Once one knew this nature then all the properties of the loadstone could be understood.

Gilbert described the nature of the loadstone in the terms of being that were current with his scholarly contemporaries. This was the same ontology that scholasticism had taught for centuries—the doctrine of form and matter that we have already found in St. Thomas and Nicholas of Cusa. Thus we find Richard Hooker⁴¹ remarking that form gives being and that "form in other creatures is a thing proportionable unto the soul in living creatures." Francis Bacon,⁴² in speaking of the relations between causes and the kinds of philosophy, said: "Physics is the science that deals with efficient and material causes

while Metaphysics deals with formal and final causes." John Donne⁴³ expressed the problem of scholastic philosophy succinctly:

This twilight of two yeares, not past or next,
Some embleme is of me, . . .
. . . of stulle and forme perplext,
Whose *what* and *where*, in disputation is . . .

As we shall see, Gilbert continued in the same tradition, but his interpretation of form and formal cause was much more anthropomorphic than that of his predecessors.

Gilbert began his *De magnete* by expounding the natural history of that portion of the earth with which we are familiar.⁴⁴

Having declared the origin and nature of the loadstone, we hold it needful first to give the history of iron also . . . before we come to the explication of difficulties connected with the loadstone . . . we shall better understand what iron is when we shall have developed . . . what are the causes and the matter of metals . . .

His treatment of the origin of minerals and rocks agreed in the main with that of Aristotle,⁴⁵ but he departed somewhat from the peripatetic doctrine of the four elements of fire, air, water, and earth.⁴⁶ Instead, he replaced them by a pair of elements.⁴⁷ (If the rejection of the four Aristotelian elements were clearer, one might consider this a part of his rejection of the geocentric universe but he did not define his position sufficiently.)⁴⁸

According to Gilbert the primary source of matter is the interior of the earth, where exhalations and "spiritus" arise from the bowels of the earth and condense in the earth's veins.⁴⁹ If the condensations, or humors, are homogeneous, they constitute the

⁴³ *The poems of John Donne*, ed. H. J. C. Grierson, London, Oxford University Press, 1933, p. 175 ("To the Countesse of Bedford, On New Yeares Day").

⁴⁴ M: pp. 33, 34.

⁴⁵ M: pp. 34, 35. Aristotle, *Works*, ed. W. D. Ross, Oxford, 1908-1952, vol. 2, *De generatione et corruptione*, translated by H. H. Joachim, 1930, vol. 3, *Meteorologica*, translated by E. W. Webster, 1931.

⁴⁶ M: pp. 34, 35, 64, 65, 69, 81. Dr. H. Guerlac has kindly brought to my attention the similarity between the explanation given in Gilbert and that given in the *Meteorologica*, bk. 3, ch. 6 p. 378.

⁴⁷ M: p. 83.

⁴⁸ A statement of the relation between Aristotle's four elements and place can be found in Maier, *op. cit.* (footnote 17), pp. 143-182.

⁴⁹ M: pp. 21, 34, 35, 36, 45.

⁴⁰ M: p. 14.

⁴¹ Richard Hooker. *Of the laws of ecclesiastical polity*, bk. 1, ch. 3, sect. 4 (*Works*, Oxford, Clarendon Press, 1865, vol. 1, p. 157).

⁴² Francis Bacon, *De augmentis scientiarum*, bk. 3, ch. 4, in *Works*, ed. J. Spedding, R. L. Ellis, and D. D. Heath, Boston, n.d. (1900?), vol. 2, p. 267.

“materia prima” of metals.⁵⁰ From this “materia prima,” various metals may be produced,⁵¹ according to the particular humor and the specifying nature of the place of condensation.⁵² The purest condensation is iron: “In iron is earth in its true and genuine nature.”⁵³ In other metals, we have instead of earth, “condensed and fixed salts, which are efflorescences of the earth.”⁵⁴ If the condensed exhalation is mixed in the vein with foreign earths already present, it forms ores that must be smelted to free the original metal from dross by fire.⁵⁵ If these exhalations should happen to pass into the open air, instead of being condensed in the earth, they may return to the earth in a (meteoric) shower of iron.⁵⁶

Gilbert was indeed writing a new physiology, both in the ancient sense of the word and the modern. The process of the formation of metals had many biological overtones, for it was a kind of metallic epigenesis.⁵⁷ “Within the globe are hidden the principles of metals and stones, as at the earth’s surface are hidden the principles of herbs and plants.”⁵⁸ In all cases, the “spiritus” acts as semen and blood that inform and feed the proper womb in the generation of animals.⁵⁹ “The brother uterine of iron,”⁶⁰ the loadstone, is formed in this manner. As the embryo of a certain species is the result of the specifying nature of the womb in which the generic seed has been placed, so the kind of metal is the result of a certain humor condensing in a particular vein in the body of the earth.

Gilbert developed this biological analogy further by ascribing to metals a process of decay after reaching

⁵⁰ M: pp. 35, 36, 38, 69; see, however, pp. 42–43: “Iron ore, therefore, as also manufactured iron, is a metal slightly different from the homogenic telluric body because of the metallic humor it has imbibed . . .”

⁵¹ M: pp. 19, 34, 36, 37, 42, 69.

⁵² M: pp. 35, 36, 37, 38.

⁵³ M: pp. 38, 63, 69, 84; on p. 34 he says that iron is “more truly the child of the earth than any other metal”; it is the hardest because of “the strong concretion of the more earthy substance.”

⁵⁴ M: pp. 21, 35, 37, 38.

⁵⁵ M: pp. 35, 63.

⁵⁶ M: pp. 45, 46.

⁵⁷ Gilbert’s terminology strongly suggests that he was familiar with alchemical literature, as well as that of medical chemistry. He has been credited as being highly skilled in chemistry. See Sir Walter Langdon-Brown, “William Gilbert: his place in the medical world,” *Nature*, vol. 154, pp. 136–139, 1944.

⁵⁸ *Ibid.*, p. 37.

⁵⁹ M: pp. 35, 36, 53, 59. See also Galen, *op. cit.* (footnote 15) bk. 2, ch. 3.

⁶⁰ M: pp. 16, 59.

maturity. Once these solid materials have been formed, they will degenerate unless protected, forming earths of various kinds as a result.⁶¹ The “rind of the earth”⁶² is produced by this process of growth and decay. If these earths are soaked with humors, transparent materials are formed.⁶³

As we shall see below, the ultimate cause of this internal and superficial life is the motion of the earth, which animation is the expression of the magnetic soul of this sphere.⁶⁴ As the life of animals results from the constant working of the heart and arteries,⁶⁵ so the daily motion of the earth results in a constant generation of mineral life within the earth. In contrast to Aristotle’s⁶⁶ making the motion of the heavens the cause of continuous change, Gilbert made that of the earth the remote cause.⁶⁷ However, unlike the constant cyclical transmutation of substances in Aristotle, there is only generation and decay.

Gilbert made a number of successive generalizations in order to arrive at the induction that the form of the loadstone is a microcosmic “anima” of that of the earth.⁶⁸ After comparing the properties of the loadstone and of iron, his first step in this induction was that the two materials, found everywhere,⁶⁹ are consanguineous:⁷⁰ “These two associated bodies possess the true, strict form of one species, though because of the outwardly different aspect and the inequality of the selfsame innate potency, they have hitherto been held to be different . . .” Good iron and good loadstone are more similar than a good and a poor loadstone, or a good and a poor iron ore.⁷¹ Moreover, they have the same potency,⁷² for the innate potency of one can be passed to the other:⁷³ “The stronger invigorates the weaker, not as if it imparted of its own substances or parted with aught

⁶¹ M: pp. 20, 21, 32, 61, 63, 66, 70.

⁶² M: p. 59.

⁶³ M: p. 84.

⁶⁴ M: pp. 310, 311, 312.

⁶⁵ M: p. 338. A somewhat different opinion, although not necessarily inconsistent is expressed on p. 66, where he says the surface is due to the action of the atmosphere, the waters, and the radiations and other influences of heavenly bodies.

⁶⁶ Aristotle, *op. cit.* (footnote 45), *De generatione et corruptione*, bk. 2, ch. 10.

⁶⁷ M: pp. 311, 334, 338.

⁶⁸ M: pp. xlvii, 309, 328.

⁶⁹ M: pp. 18, 20, 44, 46, 69.

⁷⁰ M: pp. 59, 61, 63.

⁷¹ M: pp. 60, 63.

⁷² M: p. 110.

⁷³ M: pp. 60, 61.

of its own strength, nor as if it injected into the other any physical substance; but rather the dormant power of the one is awakened by the other's without expenditure." In addition, the potency can be passed only to the other.⁷⁴ Finally they both have the same history:

We see both the finest magnet and iron ore visited as it were by the same ills and diseases, acting in the same way and with the same indications, preserved by the same remedies and protective measures, and so retaining their properties . . . they are both impaired by the action of acrid liquids as though by poison⁷⁵ . . . each is saved from impairment by being kept in the scrapings of the other. [So] . . . form, essence and appearance are one.⁷⁶

Any difference between the loadstone proper and the iron proper is due to a difference in the actual power of the magnetic virtue:⁷⁷ "Weak loadstones are those disfigured with dross metallic humors and with foreign earth admixtures, [hence one may conclude] they are further removed from the mother earth and are more degenerate."

Gilbert's second induction was that they are "true and intimate parts of the globe,"⁷⁸ that is, that they are piece of the "materia prima" of all we see about us. For they "seem to contain within themselves the potency of the earth's core and of its inmost viscera."⁷⁹ Whence, in Gilbert's philosophy, the earthy matter of the elements was not passive or inert⁸⁰ as it was in Aristotle's, but already had the magnetic powers of loadstone. Being endowed with properties, it was, in peripatetic terms, a simple body.

If these pieces of earth proper, before decay, are loadstones, then one may pass to the next induction that the earth itself is a loadstone.⁸¹ Conversely, a terrella has all the properties of the earth:⁸² "Every separate fragment of the earth exhibits in indubitable experiments the whole impetus of magnetic matter; in its various movements it follows the terrestrial globe and the common principle of motion."⁸³

⁷⁴ M: p. 62.

⁷⁵ M: p. 63.

⁷⁶ M: p. 60.

⁷⁷ M: pp. 19, 21, 43, 53, 61, 63, 184.

⁷⁸ M: p. 61.

⁷⁹ M: pp. 66, 67.

⁸⁰ M: p. 69. Gilbert is confusing Aristotelian matter and an element. He includes cold and dry, with formless and inert! See also Maier, *op. cit.* (footnote 17).

⁸¹ M: p. 63; bk. 1, ch. 17.

⁸² M: pp. 67, 181–183, 235–240, 281–289, 313–314.

⁸³ M: p. 71. See also pp. 314 and 331. It is not clear, at this point, whether he believed a "properly balanced" terrella would be a *perpetuum mobile*.

The next induction that Gilbert made was that as the magnet possesses verticity and turns towards the poles, so the loadstone-earth possesses a verticity and turns on an axis fixed in direction.⁸⁴ He could now discuss the motions of a loadstone in general, in terms of its nature, just as an Aristotelian discussed the motion of the elements in terms of their nature.

But before reaching this point in his argument, Gilbert digressed to classify the different kinds of attractions and motions which the elements produce. In particular, he distinguished electric attraction from magnetic coition, and pointed out the main features of electrical attraction. Since the resultant motions were different, the essential natures of electric and magnetic substances had to differ.

Gilbert introduced his treatment of motion by discussing the attraction of amber. All sufficiently light solids⁸⁵ and even liquids,⁸⁶ but not flame or air⁸⁷ are attracted by rubbed amber. Heat from friction,⁸⁸ but not from alien sources like the sun⁸⁹ or the flame,⁹⁰ produce this "affection." By the use of a detector modeled after the magnetic needle, which we would call an electroscope but which he called a "versorium,"⁹¹ Gilbert was able to extend the list of substances that attract like amber.⁹² These Gilbert called "electricae."⁹³

Possibly as a result of testing experimentally statements like that of St. Thomas, on the effect of garlic on a loadstone, Gilbert discovered that the interposition of even the slightest material (except a fluid like olive oil) would screen the attraction of electrics.⁹⁴ Hence the attraction is due to a material cause, and, since it is invisible, it is due to an effluvium.⁹⁵ It must be much rarer than air,⁹⁶ for if its

⁸⁴ M: pp. 68, 70–71, 97, 129, 179–180, 311, 315, 317–335. Gilbert implied (M: p. 166), that a terrella does not rotate as Peregrinus said, due to resistance (M: p. 326), or due to the mutual nature of coition (M: p. 166); or even to the rotation of the earth (M: p. 332). However (M: p. 129), he also mentioned that a terrella would revolve by itself!

⁸⁵ M: pp. 78, 82, 84, 86.

⁸⁶ M: pp. 78, 89, 91.

⁸⁷ M: pp. 89, 95.

⁸⁸ M: pp. 83, 86.

⁸⁹ M: pp. 81, 86, 87.

⁹⁰ M: pp. 80, 81, 86, 87.

⁹¹ M: p. 79.

⁹² M: pp. 77–78, 79.

⁹³ M: p. 78. The definition Gilbert gave of an electric in the glossary at the beginning of his treatise was not an experimental one: "Electricae, quae attrahunt eadem ratione ut electrum."

⁹⁴ M: pp. 86, 91, 135. ⁹⁵ M: pp. 96, 135.

⁹⁶ M: p. 89.

density were that of air or greater, it would repel rather than attract.⁹⁷

The source of the effluvia could be inferred from the properties of the electrics. Many but not all of the electrics are transparent, but all are firm and can be polished.⁹⁸ Since they retain the appearance and properties of a fluid in a firm solid mass,⁹⁹ Gilbert concluded that they derived their growth mostly from humors or were concretions of humors.¹⁰⁰ By friction, these humors are released and produce electrical attraction.¹⁰¹

This humoric source of the effluvia was substantiated by Gilbert in a number of ways. Electrics lose their power of electrical attraction upon being heated, and this is because the humor has been driven off.¹⁰² Bodies that are about equally constituted of earth and humor, or that are mostly earth, have been degraded and do not show electrical attraction.¹⁰³ Bodies like pearls and metals, since they are shiny and so must be made of humors, must also emit an effluvia upon being rubbed, but it is a thick and vaporous one without any attractive powers.¹⁰⁴ Damp weather and moist air can weaken or even prevent electrical attraction, for it impedes the efflux of the humor at the source and accordingly diminishes the attraction.¹⁰⁵ Charged bodies retain their powers longer in the sun than in the shade, for in the shade the effluvia are condensed more, and so obscure emission.¹⁰⁶

All these examples seemed to justify the hypothesis that the nature of electrics is such that material effluvia are emitted when electrics are rubbed, and that the effluvia are rarer than air. Gilbert realized that as yet he had not explained electrical attraction, only that the pull can be screened. The pull must be explained by contact forces,¹⁰⁷ as Aristotle¹⁰⁸ and

Aquinas¹⁰⁹ had argued. Accordingly, he declared, the effluvia, or "spiritus,"¹¹⁰ emitted take "hold of the bodies with which they unite, enfold them, as it were, in their arms, and bring them into union with the electrics."¹¹¹

It can be seen how this uniting action is effected if objects floating on water are considered, for solids can be drawn to solids through the medium of a fluid.¹¹² A wet body touching another wet body not only attracts it, but moves it if the other body is small,¹¹³ while wet bodies on the surface of the water attract other wet bodies. A wet object on the surface of the water seeks union with another wet object when the surface of the water rises between both: at once, "like drops of water, or bubbles on water, they come together."¹¹⁴ On the other hand, "a dry body does not move toward a wet, nor a wet to a dry, but rather they seem to go away from one another."¹¹⁵ Moreover, a dry body does not move to the dry rim of the vessel while a wet one runs to a wet rim.¹¹⁶

By means of the properties of such a fluid, Gilbert could explain the unordered coming-together that he called coacervation.¹¹⁷ Different bodies have different effluvia, and so one has coacervation of different materials. Thus, in Gilbert's philosophy air was the earth's effluvia and was responsible for the unordered motion of objects towards the earth.¹¹⁸

The analogy between electric attraction and fluids is a most concrete one, yet lying beneath this image is a hypothesis that is difficult to fix into a mechanical system based upon contact forces. This is the assumption that under the proper conditions bodies tend to move together in order to participate in a more

¹⁰⁹ St. Thomas Aquinas, *op. cit.* (footnote 19), vol. 2, *Physicorum Aristotelis expositio*, lib. 7, lect. 2 (In moventibus et motis non potest procedi in infinitum, sed oportet devenire ad aliquod primum movens immobile), cap. d, p. 96.

¹¹⁰ M: p. 94.

¹¹¹ M: p. 95.

¹¹² M: p. 93.

¹¹³ M: pp. 92, 93.

¹¹⁴ M: p. 93.

¹¹⁵ M: p. 94.

¹¹⁶ M: p. 94.

¹¹⁷ M: p. 97.

¹¹⁸ M: p. 92 (see also p. 339). Although Gilbert does not make it explicit, this would solve the medieval problem of gravitation without resorting to a Ptolemaic universe. In addition, since coacervation is electric, and electric forces can be screened, it should have been possible to reduce the downward motion of a body by screening!

⁹⁷ M: pp. 90, 92, 95.

⁹⁸ M: pp. 83, 84, 85.

⁹⁹ M: p. 84.

¹⁰⁰ M: pp. 84, 89. See also Aristotle, *op. cit.* (footnote 45), *Meteorologica*, bk. 4.

¹⁰¹ M: p. 90.

¹⁰² M: pp. 84, 85.

¹⁰³ M: p. 84.

¹⁰⁴ M: p. 90. See also p. 95.

¹⁰⁵ M: pp. 78, 85-86, 91. (see particularly the heated amber experiment described on p. 86).

¹⁰⁶ M: p. 87.

¹⁰⁷ M: p. 92.

¹⁰⁸ Aristotle, *Physics*, translated by P. H. Wicksteed and F. M. Cornford, Loeb Classical Library, London, 1934, bk. 7, ch. 1, 242b25,

complete unity.¹¹⁹ The steps in electrical attraction were described as occurring on two different levels of abstraction: first one has physical contact through an effluvium or "spiritus" that connects the two objects physically. Then, as a result of this contact, the objects somehow sense¹²⁰ that a more intimate harmony is possible, and move accordingly. Gilbert called the motion that followed contact, attraction. However, this motion did not connote what we would call a force:¹²¹ it did not correspond directly to a push or pull, but it followed from what one might term the apprehension of the possibility of a more complete participation in a formal unity. The physical unity due to the "spiritus" was the prelude to a formal organic unity, so that *humor* is "rerum omnium unitore." Gilbert's position can be best seen in the following:¹²²

Spiritus igitur egrediens ex corpora, quod ab humore aut succo aqueo concreverat, corpus attrahendum attingit, attractum attrahenti unitur; corpus peculiari effluviolum radio continguum, unum efficit ex duobus: unita conflunt in conjunctissimam convenientiam, quae attractio vulgo dicitur. Quae unitas iuxta Pythagorae opinionem rerum omnium principium est, per cuius participationem unaquaeque res una dicitur. Quoniam enim nullo actio a materia potest nisi per contactum, electrica haec non videntur tangere, sed ut necesse erat demittitur aliquid ab uno ad aliud, quod proxime tangat, et eius incitationis principium sit. Corpora omnia ununtur & quasi ferruminantur quodammodo humore . . . Electrica vero effluvia peculiariter, quae humoris fusi subtilissima sunt materia, corpuscula allectant. Aer (commune effluviolum telluri & partes disjunctis unit, & tellus mediante aëre ad se revocat corpora; aliter quae in superioribus locis essent corpora, terram non ita avidè appellerent.

Electrica effluvia ab aëre multum differunt, & ut aer telluris effluviolum est, ita electrica suahabent effluvia & propria; peculiaribus effluviis suis cuique; est singularis ad unitatem ductus, motus ad principium, fontem, & corpus effluvia emittens.

A similar hypothesis will reappear in his explanation of magnetic attraction.

Following the tradition of the medieval schoolmen Gilbert started his examination of the nature of the

¹¹⁹ M: pp. 91, 92: "This unity is, according to Pythagoras, the principle, through participation, in which a thing is said to be one" (see footnotes 30 and 122).

¹²⁰ "Sense" is probably too strong a term, and yet the change following contact is difficult to describe in Gilbert's phraseology without some such subjective term. See Gilbert's argument on the soul and organs of a loadstone, M: pp. 309-313.

¹²¹ M: pp. 112, 113.

¹²² Gilbert, *De magnete*, London, 1600, bk. 2, ch. 2, pp. 56-57.

loadstone by pointing out the different kinds of motion due to a magnet. The five kinds (other than up and down) are:¹²³

- (1) coitio (vulgo attractio, dicta) ad unitatem magneticam incitatio.
- (2) directio in polos telluris, et telluris in mundi destinatos terminos verticitas et consistentia.
- (3) variatio, a meridiano dellexio, quem motum nos depravatam dicimus.
- (4) declinatio, infra horizontem poli magnetici descensus.
- (5) motus circularis, seu revolutio.

Of the five he initially listed, three are not basic ones. Variation and declination he later explained as due to irregularities of the surface of the earth, while direction or verticity is the ordering motion that precedes coition.¹²⁴ This leaves only coition and revolution as the basic motions. How these followed from "the congregant nature of the loadstone can be seen when the effusion of forms has been considered."

Coition (he did not take up revolution at this point) differed from that due to other attractions. There are two and only two kinds of bodies that can attract: electric and magnetic.¹²⁵ Gilbert refined his position further by arguing that one does not even have magnetic attraction¹²⁶ but instead the mutual motion to union that he called coition.¹²⁷ In electric attraction, one has an action-passion relation of cause and effect with an external agent and a passive recipient; while in magnetic coition, both bodies act and are acted upon, and both move together.¹²⁸ Instead of an agent and a patient in coition,¹²⁹ one has "contactus." Coition, as the Latin origin of the term denoted, is always a concerted action.¹³⁰ This can be seen from the motions of two loadstones floating on water.¹³¹ The mutual motion in coition was one of the reasons for Gilbert's rejection of the perpetual motion machine of Peregrinus.¹³²

Magnetic coition, unlike electric attraction, cannot be screened.¹³³ Hence it cannot be corporeal for it

¹²³ *Ibid.*, ch. 1, pp. 45-46.

¹²⁴ M: pp. 110, 314.

¹²⁵ M: pp. 82, 105, 170, 172, 217.

¹²⁶ M: p. 98.

¹²⁷ M: pp. 100, 112, 113, 143, 148. It need hardly be pointed out that coitus is not an impersonal term.

¹²⁸ M: p. 110.

¹²⁹ M: p. 110.

¹³⁰ M: pp. 109, 115, 148, 149, 155, 166, 174.

¹³¹ M: pp. 110, 155.

¹³² M: pp. 166, 332. See also footnote 84.

¹³³ M: pp. 90, 106, 107, 108, 113, 132, 135, 136, 158. This is, of course, contrary to modern experience.

travels freely through bodies¹³⁴ and especially magnetic bodies;¹³⁵ one can understand the action of the armature on this basis.¹³⁶ Since coition cannot be prevented by shielding, it must have an immaterial cause.¹³⁷

Yet, unless one has the occult action-at-a-distance, change must be caused by contact forces. Gilbert resolved the paradox of combining contact forces with forces that cannot be shielded, by passing to a higher level of abstraction for the explanation of magnetic phenomena; he saw the contact as that of a form with matter.

Although Gilbert remarked that the cause of magnetic phenomena did not fall within any of the categories of the formal causes of the Aristotelians, he did not renounce for this reason the medieval tradition. Actually there are many similarities between Gilbert's explanation of the loadstone's powers and that of St. Thomas. Magnetic coition is not due to any of the generic or specific forms of the Aristotelian elements, nor is it due to the primary qualities of any of their elements, nor is it due to the celestial "generans" of terrestrial change.¹³⁸

Relictis aliorum opinionibus de magnetis attractione; nunc coitionis illius rationem, et motus illius commoventem naturam docebimus. Cum vero duo sint corporum genera, quae manifestis sensibus nostris motionibus corpora allicere videntur, Electrica et Magnetica; Electrica naturalibus ab humore effluviis; Magnetica formalibus efficientiis, seu potius primariis vigoribus, incitationes faciunt. Forma illa singularis est, et peculiaris, non Peripateticorum causa formalis, et specifica in mixtis, est secunda forma, non generantium corporum propagatrix; sed primorum et praeciporum globorum forma; et partium eorum homogenearum, non corruptarum, propria entitas et existentia, quam nos primariam, et radicalem, et astream appellare possumus formam; non formam primam Aristotelis; sed singularem illam, quae globum suum proprium uctur et disponit. Talis in singulis globis, Sole, lunas et astris, est una; in terra etiam una, quae vera est illa potentia magnetica, quam nos primarium vigorem appellamus. Quare magnetica natura est telluris propria, eiusque omnibus verioribus partibus, primaria et stupenda ratione, insita; haec nec a caelo toto derivatur procreaturve, per sympathiam, per influentiam, aut occultiores qualitates; nec peculiari aliquo astro: est enim suus in tellure magneticus

¹³⁴ M: pp. 106, 107, 108, 114, 134, 136, 140, 162.

¹³⁵ M: pp. 106, 109, 114, 159, 162.

¹³⁶ M: pp. 137-140.

¹³⁷ M: p. 109.

¹³⁸ M: p. 105, and Gilbert, *De magnete*, London, 1600, bk. 2 ch. 4, p. 65.

vigor, sicut in sole et luna suae formae; frustulumque; lunae, lunatice ad eius terminos, et formam componit se; solarque; ad solem, sicut magnes ad tellurem, et ad alterum magnetem, secundum naturam sese inclinando et alliciendo. Differendum igitur de tellure quae magnetica, et magnes; tum etiam de partibus eius verioribus, quae magneticae sunt; et quomodo ex coitione difflucuntur.

Instead, he declared it to be due to a form that is natural and proper to that element that he made the primary component of the earth.¹³⁹

To understand his argument, let us briefly recall the peripatetic theory of the elements. In this philosophy of nature each element or simple body is a combination of a pair of the four primary qualities that informs inchoate matter. These qualities are the instruments of the elemental forms and determine the properties of the element. Thus the element fire is a compound of the qualities hot and dry, and the substantial form of fire acts through these qualities. Similarly for the other elements, earth, water, and air: their forms determine a proper place for each element, and a motion to that place natural to each element.¹⁴⁰

Gilbert had previously declared that the primary substance of the earth is an element. Since it is an element, it has a motion natural to it, and this motion is magnetic coition. As an Aristotelian considered the substantial form of the element, fire, to act through the qualities of hot and dry, and to cause an upward motion; so Gilbert argued that the substantial form of his element, pure loadstone, acts through the magnetic qualities and causes magnetic coition. This motion is due to its primary form, and is natural to the element earth.¹⁴¹ It is instilled in all proper and undegenerate parts of the earth,¹⁴² but in no other element.¹⁴³

To the medieval philosopher, the "generantia" of the occult powers of the loadstone are the heavenly bodies. Gilbert, however, endowed the earth with these heavenly powers which were placed in the earth in the beginning¹⁴⁴ and caused all magnetic materials to conform with it both physically and

¹³⁹ M: p. 105.

¹⁴⁰ M: pp. 289, 322.

¹⁴¹ M: pp. 26, 68, 105, 179, 198, 307, 335, 343. For rotation, see footnote 147.

¹⁴² M: pp. 67, 71. That each part is informed with the properties of the whole is an argument favoring an animistic explanation of the nature of this form.

¹⁴³ M: p. 109.

¹⁴⁴ M: pp. 111, 188.

formally.¹⁴⁵ Such magnetic powers are the property of all parts of the earth;¹⁴⁶ they give the earth its rotating motion¹⁴⁷ and hold the earth together in spite of this motion.¹⁴⁸

Indeed, each of the main stellar bodies, sun, moon, stars, and earth, has such a form or principle unique to itself that causes its parts not only to conform with itself but to revolve.¹⁴⁹ Thus, if one removes a piece of the moon from this body, it will tend to align itself with the moon and then to return to its proper place; and a fragment of the sun would similarly tend to return after proper orientation.¹⁵⁰ Moreover, there is a farther-ranging, though weaker, mutual action of the heavenly bodies so that one has a causal hierarchy of these specific conforming powers. The form of the sun is superior to that of the inferior globes and is responsible for the order and regularity of planetary orbits.¹⁵¹ In like manner, the moon is responsible for the tides of the ocean.¹⁵²

By virtue of the causal hierarchy of forms, the loadstone acquires its magnetic powers from the earth.¹⁵³ As the earth has its natural parts, so has the stone.¹⁵⁴ Although the geometrical center of a terrella is the center of the magnetic forces,¹⁵⁵ objects do not tend to move to the center but to its poles,¹⁵⁶ where the magnetic energy is most conspicuous.¹⁵⁷ However, in a sense, the energy is everywhere equal: the virtue is spread throughout the entire mass of the loadstone,¹⁵⁸ and all the parts direct the forces to the poles.¹⁵⁹ The poles become the “thrones” of the magnetic powers.¹⁶⁰ On the other hand, the directive force is stronger where cohesion is weaker and accordingly, verticity is most prominent at the equator.¹⁶¹

The strength of a loadstone depends upon its shape and mass. A bar magnet has greater powers than a spherical one because it tends to concentrate the magnetic powers more in the ends.¹⁶² For a given purity and shape, the heavier the loadstone, the greater its strength.¹⁶³ A loadstone has a maximum degree of magnetic force that cannot be increased.¹⁶⁴ However, weaker ones can be strengthened by stronger ones.¹⁶⁵ Similarly, the shape and weight of the iron determine the magnetic force in cohesion.¹⁶⁶

The formal forces of a loadstone emanate in all directions from it,¹⁶⁷ but there is a bound to it that Gilbert called the “*orbis virtutis*.”¹⁶⁸ The shape of this “*orbis virtutis*” is determined by the shape of the stone.¹⁶⁹ This insensible effusion is analogous to the spreading of light that reveals its presence only by opaque bodies.¹⁷⁰ Similarly, the magnetic forms are effused from the stone,¹⁷¹ and can only reveal their presence by cohesion with another loadstone or by “awakening” magnetic bodies within the “*orbis virtutis*.”¹⁷² Unmagnetized iron that comes within the “*orbis virtutis*” is altered, and the magnetic virtue renews a form that is already potentially in the iron.¹⁷³ The formal energy is drawn not only from the stone but from the iron.¹⁷⁴ This is not generation, or alteration in the sense of a new impressed quality, but alteration in the sense of the entelechy or the activation of a form potentially present.¹⁷⁵ Those bodies

¹⁶² M: pp. 131, 132, 153–158.

¹⁶³ M: pp. 141, 152, 153, 158, 161, 191, 222.

¹⁶⁴ M: p. 146.

¹⁶⁵ M: p. 165.

¹⁶⁶ M: p. 153.

¹⁶⁷ M: pp. 121, 123, 124, 304, 305, 306, 307, 309.

¹⁶⁸ Gilbert defined the *orbis virtutis* in the glossary at the beginning of his treatise as, “. . . totum illud spatium, per quod quaevis magnetis virtus extenditur.” This is the core of the difference between electric and magnetic forces. The substantial form of an electric could not be “effused,” but was “imprisoned” in matter (as the Neoplatonic soul in the human body); while the primary form of a magnet did not require a material carrier and its effusion was similar to the propagation of a species in light.

¹⁶⁹ M: pp. 124, 150, 151.

¹⁷⁰ M: pp. 123, 307.

¹⁷¹ M: pp. 304–307. See also p. 310, where it is stated that the sun and earth could awaken souls.

¹⁷² M: pp. 101, 110, 112, 123, 148, 149, 304, 305. This awakening of the iron within the “*orbis virtutis*” is comparable (pp. 216, 350) to the birth of a child under the influence of the stars.

¹⁷³ M: pp. 110, 111, 112, 189, 216, 217. See also footnote 36.

¹⁷⁴ M: p. 106.

¹⁷⁵ M: pp. 106, 109, 110.

¹⁴⁵ M: pp. 67, 105, 179, 183.

¹⁴⁶ M: pp. 101, 105, 217.

¹⁴⁷ M: pp. 179, 304, 305, 311, 322, 326, 328, 330–334, 338–343.

¹⁴⁸ M: pp. 142, 179; see also electric attraction, p. 97.

¹⁴⁹ M: pp. 308, 317–343.

¹⁵⁰ M: pp. 106, 340.

¹⁵¹ M: pp. 308, 309, 311, 330, 333, 344, 347.

¹⁵² M: pp. 136, 334, 345.

¹⁵³ M: pp. 184–186, 190, 232. This is not quite the same argument as that the powers of the loadstone are identical with those of the earth. See footnote 78.

¹⁵⁴ M: pp. 125, 180.

¹⁵⁵ M: p. 151.

¹⁵⁶ M: pp. 121, 150.

¹⁵⁷ M: pp. 115, 151, 165.

¹⁵⁸ M: pp. 106, 118, 151, 191, 205, 221, 243.

¹⁵⁹ M: pp. 116, 117, 119, 131, 183, 188, 221.

¹⁶⁰ M: p. 31.

¹⁶¹ M: pp. 116, 151, 200.

magnetized by coming within the "orbis virtutis" have in turn an efflux of their own.¹⁷⁶ Iron can also receive verticity directly from the earth without the intervention of an ordinary loadstone.¹⁷⁷ Such verticity can be expelled and annulled by the presence of another loadstone.¹⁷⁸

Although one does not normally find iron to be magnetized, a loadstone always has some magnetism. That two bodies such as iron and loadstone should have different properties is the result of the loss of a form by the iron, but this form is still potentially present in the iron. The iron that has been obtained from an ore has been deformed,¹⁷⁹ for it has been placed "outside its nature" by the fire.¹⁸⁰ The nature has not been removed, since, once the iron has cooled, the confused form can be reformed by a loadstone.¹⁸¹ The latter "awakens" the proper form of iron.¹⁸² After smelting, the magnetized iron may manifest stronger powers than a loadstone of equal weight, but this is because the primary matter of the earth is purer in the iron than in the loadstone.¹⁸³ If fire does not deform a loadstone too much, it can be remagnetized,¹⁸⁴ but a burnt loadstone cannot be reformed.¹⁸⁵ Corruption from external causes may also deform a loadstone or iron so that it can not be magnetized.¹⁸⁶ Bodies mixed with the degenerate substance of the earth or with aqueous humor spoilt by contamination with earth, do not show either electric attraction or magnetic coition.¹⁸⁷

In a manner suggestive of Peregrinus, Gilbert wrote that, "magnetic bodies seek formal unity."¹⁸⁸ Thus a dissected loadstone not only tends to come back together, as in the unordered coacervation of electric attraction, but to restore the organization it had before dissection.¹⁸⁹ Accordingly, opposite poles appear on the interfaces of the sections, not "from an opposition" but from "a concordance and a conformance."¹⁹⁰ This ensures that when the

parts are joined together again, they have the same orientation as before. Gilbert compared this power of restoring the original loadstone with that of a plant's vital power under the process of cutting and grafting; the plant can be revived only when the parts are in a certain order.¹⁹¹

A hypothesis similar to that used to explain electric attraction lay beneath the explanation of magnetic coition: that bodies brought into contact will move together. In electric attraction, the contact is material and due to the "spiritus" from the electric body; in magnetic coition, it is formal and depends on the action of a primary form that spreads from a magnetized body to its limit of effusion, the "orbis virtutis." If iron is inside the "orbis virtutis," the two bodies "enter into alliance and are one and the same"¹⁹² for within it "they have absolute continuity, and are joined by reason of their accordance, albeit the bodies themselves be separated."¹⁹³

Gilbert's treatment of coition can be analyzed into the same two steps as can electric attraction. First occurs a contact, which in this case is not physical but formal, and from this initial formal contact follows movement to a more complete unity. Both the contact and the movement to unity are described on the same level of abstraction, instead of on two different levels as in electric attraction. Again one does not find any clear-cut concept of force as a push or pull,¹⁹⁴ but instead, a motion to a formal unity, this time a cooperative motion. The parts of a magnetic body are in greater harmony when they are assembled in a certain pattern and so they move accordingly.

As to the nature of the primary form itself, Gilbert agreed with Thales that it is like a soul,¹⁹⁵ "for the power of self-movement seems to betoken a soul."¹⁹⁶ With Galen and St. Thomas he placed the form of the loadstone superior to that of inanimate matter.¹⁹⁷ In a sense, Gilbert even made it superior to organic matter, for it is incapable of error.¹⁹⁸ Like the soul, the primary form cannot be fragmented; when a loadstone is divided, one does not separate the poles but each part acquires its own poles and an equator.

¹⁷⁶ M: pp. 113, 114.

¹⁷⁷ M: pp. 190, 192, 210-216.

¹⁷⁸ M: p. 209.

¹⁷⁹ M: pp. 107, 110, 111.

¹⁸⁰ M: p. 108.

¹⁸¹ M: pp. 111, 112, 113.

¹⁸² M: pp. 109, 111, 112, 148, 149.

¹⁸³ M: pp. 112, 149.

¹⁸⁴ M: pp. 142, 189.

¹⁸⁵ M: p. 190.

¹⁸⁶ M: pp. 85, 105, 113, 143, 226.

¹⁸⁷ M: p. 84.

¹⁸⁸ M: p. 186.

¹⁸⁹ M: pp. 185-188. See also footnote 31.

¹⁹⁰ M: pp. 186, 193.

¹⁹¹ M: pp. 199-200.

¹⁹² M: p. 111.

¹⁹³ M: p. 112.

¹⁹⁴ See, however, M: pp. 112, 113.

¹⁹⁵ M: pp. 109, 312.

¹⁹⁶ M: p. 109.

¹⁹⁷ M: p. 309.

¹⁹⁸ M: pp. 311-312.

Like the soul, fire does not destroy it.¹⁹⁹ Like the soul of astral bodies, and of the earth itself, it produces complex but regular motions; the motion of two loadstones on water offers such an example.²⁰⁰ Like the soul of a newborn child, whose nature depends on the configuration of the heavens, the properties in the newly awakened iron depend upon its position in the "orbis virtutis."²⁰¹

Whence Gilbert declared:

. . . the earth's magnetic force and the animate form of the globes, that are without senses, but without error . . . exert an unending action, quick, definite, constant, directive, motive, imperant, harmonious through the whole mass of matter; thereby are the generation and the ultimate decay of all things on the superficies propagated.²⁰² The bodies of the globes . . . to the end that they might be in themselves, and in their nature endure, had need of souls to be conjoined to them, for else there were neither life, nor prime act, nor movement, nor union, nor order, nor coherence, nor *contactus*, nor *sympathia*, nor any generation nor alteration of seasons, and no propagation; but all were in confusion . . .²⁰³ Wherefore, not with reason, Thales . . . declares the loadstone to be animate, a part of the animate mother earth and her beloved offspring.²⁰⁴

Gilbert ended book 5 of his treatise on the magnet with a persuasive plea for his magnetic philosophy of the cosmos, yet his conceptual scheme was not too successful an induction in the eyes of his contemporaries. In particular the man from whom the Royal Society took the inspiration for their motto, "Nullius in verba," did not value his magnetic philosophy very highly. Whether Francis Bacon was alluding to Gilbert when he expounded his parable of the spider and the ant²⁰⁵ is not explicit, but he certainly had him in mind when he wrote of the Idols of the Cave and the Idols of the Theater.²⁰⁶

Few of the subsequent experimenters and writers on magnetism turned to Gilbert's work to explain the effects they discussed. Although both his countrymen Sir Thomas Browne²⁰⁷ and Robert Boyle²⁰⁸ de-

scribed a number of the experiments already described by Gilbert and even used phrases similar to his in describing them, they tended to ignore Gilbert and his explanation of them. Instead, both turned to an explanation based upon magnetic effluvia or corpuseles. The only direct continuation of Gilbert's *De magnete* was the *Philosophia magnetica* of Nicolaus Cabeus.²⁰⁹ The latter sought to bring Gilbert's explanation of magnetism more directly into the fold of medieval substantial forms.

However, Gilbert's efforts towards a magnetic philosophy did find approval in two of the men that made the seventeenth century scientific revolution. While Galileo Galilei²¹⁰ was critical of Gilbert's arguments as being unnecessarily loose, he nevertheless saw in them some support for the Copernican world-system. Johannes Kepler²¹¹ found in Gilbert's explanation of the loadstone-earth a possible physical framework for his own investigations on planetary motions.

Yet Galileo and Kepler had moved beyond Gilbert's world of intellectual experience. They were no longer concerned with determining the nature of material things in order to explain their qualities. Instead, they had passed into the realm of the mathematical relations of kinematics: quantitative law had replaced qualitative experience of cause and effect. Gilbert had some intimations of the former, but he was primarily concerned with explaining magnetism in terms of substance and attribute. He had to ascertain the nature of the loadstone and of the earth in order to explain their properties and their motions. He even went further and explained the nature of the form of the loadstone.

His method of determining the nature of a substance was a rather primitive one—it was not by a process of induction and deduction, nor by synthesis and analysis, nor by "resolutio" and "compositio," but by the use of analogies. He compared the natural history of metals and rocks with that of plants, and gave the two former the same kind of principle as the last. He determined the nature of the entity behind electric attraction by finding that such attractions could be screened, and hence it had to be corporeal. After comparing this "corporeal" attraction with that of

¹⁹⁹ M: p. 108.

²⁰⁰ M: p. 110.

²⁰¹ M: p. 216.

²⁰² M: p. 311.

²⁰³ M: pp. 310, 311.

²⁰⁴ M: p. 312.

²⁰⁵ Francis Bacon, *op. cit.* (footnote 42), vol. 1, *Novum organum*, bk. 1, ch. 95, p. 306.

²⁰⁶ *Ibid.*, ch. 54 and ch. 64 (pp. 259 and 267).

²⁰⁷ Sir Thomas Browne, *Pseudodoxia epidemica*, ed. 3, London, 1658, bk. 2, ch. 2, 3, 4.

²⁰⁸ Robert Boyle, *Experiments and notes about the mechanical production of magnetism*, London, 1676.

²⁰⁹ Nicolaus Cabeus, *Philosophia magnetica*, Ferrara, 1629.

²¹⁰ Galileo Galilei, *Dialogue on the great world systems*, in the translation of T. Salusbury, edited and corrected by G. de Santillana, University of Chicago Press, 1953, pp. 409–423.

²¹¹ Cassirer, *op. cit.* (footnote 3), vol. 1, p. 359–367.

the surface forces of a fluid, he concluded that the entity was a subtle fluid. He determined the nature of the entity behind magnetic cohesion by (incorrectly) finding that it cannot be screened, and hence the cause had to be a formal one. Since both stars and the loadstone can carry out regular motions, and stars had souls, the form of the loadstone had to be a soul. The method of analogy was used again in his comparison of the properties of a magnetized needle placed over a terrella with the properties of a compass placed over the earth, whence he concluded the earth to be a giant loadstone. Since the earth resembled the other celestial globes, it had to have, the circular inertia of these globes.²¹² As for his magnetic experiments to show physically that the earth moved, and his unbridled speculations on the "animae" of the celestial globes, one is inclined to agree with Bacon's estimate of his magnetic philosophy.

One might consider Gilbert's book as a Renaissance recasting of Aristotle's *De caelo* with the earth in the role of a heavenly body. So it might well be, for Gilbert was still concerned with distinguishing the nature of the heavenly body, earth, that caused the coitional and revolving motions, from those natures for which up and down, and coacervation were the natural motions. Because the natural motions were different, the natures had to be different, and these different natures led to a universe and a concept of space neither of which were Aristotelian. One no longer had a central reference point for absolute space; there was no "motor essentialis" focused upon the earth but one had only the mutual motion of the heavenly bodies. The natural distinction between heaven and earth was gone, for the earth was no longer an inert recipient but a source of wonder, and so the stage was set for the universe

²¹² Because the earth has the same nature as a celestial globe, its revolution and circular inertia require no more explanation than those of any other heavenly body.

of Giordano Bruno.²¹³ The Aristotelian philosophy of nature was used to justify a new cosmology, but there was no break with the past such as one finds in Galileo and Kepler. Instead he followed the chimera of the world organism, as Paracelsus had, and of the world soul, as Bruno had. Consequently Gilbert's physiology did not enter into the main stream of science.

Yet this is not to deny Gilbert's services to natural philosophy. Although not all of his experimental distinction between electric and magnetic forces has been retained, still, some of it has. His "orbis virtutis" was to become a field of force, and his class of electrics, insulators of electricity. His practice of arming a loadstone was to be of considerable importance in the period before the invention of the electromagnet. His limited recognition of the mutual nature of forces and their quantitative basis in mass was ultimately to appear in Newton's second and third laws of motion. In spite of the weaknesses of the method of analogy, Gilbert's experimental model of the terrella to interpret the earth's magnetism was as much a contribution to scientific method as to the theory of magnetism.

Consequently, in spite of an explanation of electricity and magnetism that one would be amused to find in a textbook today, we can still read his *De magnete* with interest and profit. But more important than his scientific speculations, is the insight he can give us into a Renaissance philosophy of nature and its relation to medieval thought. One does not find in *De magnete* a prototype of modern physical science in the same sense one can in the writings of Galileo and Kepler. Instead one finds here a full-fledged example of an earlier kind of science, and this is Gilbert's main value to the historian today.

²¹³ One wonders if Bruno might not have been another of the stimuli for Gilbert. The latter's interest in magnetism began shortly before Bruno visited England and lectured on his interpretation of the Copernican theory.

