

THEORIES OF MAGNETISM IN THE CHRISTIAN ERA

H.H. Ricker III

Email: kc3mx@yahoo.com

Introduction

The purpose of this chapter is to discuss the history of magnetism during the age of power of the Christian church. This covers the period known as the dark or middle ages from the dissolution of the western Roman empire to the birth of modern science about 1600. It covers the entire medieval period, but there is little of interest prior to the publication of the epistle on the magnet. The period covers a lot of ground historically, but very little is of interest for our history of electricity and magnetism. There were no other magneticans of renown like Peter Peregrinus, who stands alone as a landmark in the history of magnetism. There were many lesser philosophers as well as great minds, ready to give their opinion on it. The great minds of the period were not concerned with magnetism, they were concerned with larger issues into which magnetic phenomena crept as part of a larger problem. Because the period is dominated by Christian philosophy, this is the dominant theme of this section.

Towards the end of the period, with the resurrection of Aristotelian scientific method, there is a stunning development. A magnetic theory, Aristotelian in its foundations, is developed during the later middle ages. We will see that only the slightest hints it have survived, so that a full and complete description is not possible.

The period has a very bad reputation, “,,, the spirit and practice of medieval times were always unfriendly to science....During nearly one thousand years, science was neglected.”¹ If we were to subscribe to this belief, we would certainly expect to find nothing of value during this period. In refutation of this opinion we discover Peter Peregrinus and his beautiful epistola. So there may be more treasure to discover here that justifies the effort. Indeed this is the case.

The most important development in the science of magnetism was the advancement of the Aristotelian theory of magnetism in the hands of the Christian philosophers, sometimes called the Scholastics or schoolmen. During the 12th and 13th centuries, there was a rebirth of learning in western europe stimulated by the translation of ancient Greek texts from Arabic into Latin. This was accompanied by the acquisition of the works of the Arabs as well. The most important were the works of Averroes, a Moslem scholar who lived in the Arabic kingdom of Andalusia, in southern Spain.

The Aristotelian theory of the scholastic period was a non-materialistic theory that can be considered an extension of the Thalean idea of the magnet. It is a very primitive field theory, employing the conception of the occult or hidden force to explain the action without a material cause. It is remarkably similar to the modern ideas regarding the attraction of iron.

Towards the end of the period there is another upheaval of importance. This was the growing interest in magic and astrology that occurred in the renaissance. In truth it is a reaction against the power of the Christian Church and its sanctioned teachings including the scholastic version

of Aristotelianism. One aspect of this reaction is the increased activity of the inquisition. This institution has a bad reputation because it has been labeled as the oppressor of progress. But, it was instrumental in suppressing many of the superstitious beliefs which modern society is also pitted against. Witchcraft, black magic and other forbidden magic arts were suppressed using the inquisition. The Church was also opposed to technological development, for reasons very much the same as modern opposition to science. The Church abhorred the invention of military weapons, because they increased the destruction of human life. Sometimes these efforts are ignored and science histories merely reflect the Church's opposition to the progress of learning. But, this learning, as in the case of Galileo, may have been in the areas forbidden by the Church for very enlightened reasons.

Saint Augustine Sets the Stage for Christian Science

Few men have influenced philosophy and religion as effectively as Saint Augustine of Hippo. His life marks the zenith of philosophical thought during the Christian Roman era. Following the conversion to Christianity, the empire continued to flourish until shortly after Augustine's death in 430. Born in 354 in North Africa, his legacy was undoubtedly one of the most influential of the Christian era. But the empire was crumbling around him at the time of his death. The Vandal armies had invaded Roman Africa, and the once prosperous province was in ruins. In a few years the western empire would follow.²

Saint Augustine's philosophy of scientific thought was basically religious. It stressed that nature, or the universe, is the work of a morally good intelligent creator:

"Everything that You made was good, and there is nothing at all which You did not make...Each thing by itself is good, and the sum of them all is very good."

He conceived of nature as a sign of God. As a sign, the world is transparent to God in it. Augustine's science was fundamentally a religious enterprise. This idea profoundly influenced science of the later Christian ages. Here we see that there is a strong link to the fundamental ideas which motivated Thales scientific speculations in the sixth century before Christ; a thousand years before Augustine.²

Between the years 413 and 426 Saint Augustine, of Hippo (354-430) published The City Of God, a work defining Christian philosophy. In a digression discussing amazing phenomena which appear to be miracles yet are true phenomena, he describes in his own words how he witnessed the miracle of the loadstone.³

"We know that the loadstone has a wonderful power of attracting iron. When I first saw it I was thunderstruck, for I saw an iron ring attracted and suspended by the stone; and then, as if it had communicated its own property to the iron it attracted, and had made it a substance like itself, this ring was put near another, and lifted it up; and as the first ring clung to the magnet, so did the second ring to the first. A third and a fourth were similarly added, so that there hung from the stone a kind of chain of rings, with their hoops connected, not interlinking, but attracted together by their outer surface. Who would not be amazed at this virtue of the stone, subsisting

as it does not only in itself, but transmitted through so many suspended rings, and binding them together by invisible links?”³

This is a beautiful description of magnetic induction, and one of the earliest descriptions of an experiment involving magnetism. It describes the phenomenon accurately, and contains the seed of an interpretation. This seed is the idea that the magnetic attraction “communicates its own property to the iron....and had made it a substance like itself.” This is the fundamental idea that underlies the theory of magnetism which is developed by the Christian philosophers of the middle ages. Clearly it is borrowed from or inspired by Plato’s “Ion” and Galen’s criticism of Epicurus. Notice also the use of the Aristotelian concept of substance.

Augustine continues to describe another experiment which was as amazing as the first. The experiment was witnessed by his brother while being entertained at dinner. His host

“...produced a magnet, and held it under a silver plate on which he placed a bit of iron; then as he moved his hand with the magnet underneath the plate, the iron upon the plate moved about accordingly. The intervening silver was not effected at all, but precisely as the magnet was moved backwards and forwards below it, no matter how quickly, so was the iron attracted above.”³

In a later chapter, Augustine shows clearly that he understood the distinction between the electric and magnetic attraction. This distinction separating electricity from magnetism continued until the unification into electromagnetism occurred in the 19th century. Augustine says,

“For my own part, I do not wish all the marvels I have cited to be rashly accepted, for I do not myself believe them implicitly, save those which have come under my own observation, or which any one can readily verify such as...the magnet which by its mysterious and insensible suction attracts the iron, but has no effect on a straw...”³

This passage shows that Augustine clearly understood the difference between magnetic and electric attractions. Magnetism only acts on iron, but not straw, while amber attracts straw but not iron. This distinction becomes important to philosophers of later ages, who use it to distinguish the magnetic virtue from the electric virtue. Augustine’s observations in a Christian text are important for two reasons. It shows the openness of Christian philosophers to experimental knowledge, and indicates that proof by demonstration was not an idea alien to them.

Another aspect of these experiments is that they show clearly why the materialist theory of the magnet must be invalid. We have already seen how Galen criticized the Epicurean theory because it failed to explain magnetic induction. Augustine repeats the experiment and shows how it is marvelous. How was it possible to explain the transmission of the magnetic attraction from the magnet to the hanging rings? This becomes an insurmountable difficulty for the materialistic theory. It was a difficulty that all Christian scholars were clearly aware of, because it was described in one of the fundamental works of Christian philosophy. The second major difficulty is the transmission of the magnetic attraction through the silver plate. How could this be if the attraction is caused by material particles. Even if very small, they must be blocked by the

intervening silver. The action of the air and effluvia by the circular thrust was also definitely ruled out as an explanation, because the circular thrust would be blocked by the presence of the intervening plate. The problem is framed as a physical transmission of the attractive force, but this occurs through intervening material. Augustine asks us to consider how this can be possible given a materialistic theory, and suggests a possible explanation using Aristotelian principles. This is the basic concept that is elaborated by the Christian philosophers of the middle ages.

The Aristotelian Explanation Of Magnetic Movement

Following the fall of the western Roman Empire, there was a long period of civil upheaval. Frequent invasions from outside prevented any progress in the restoration of a civilized culture. The Christian church became fragmented as the Roman church's power became confined only to Rome. This period does not have any significance for our history, except to note that it was a period of dramatic change. There was a tremendous influx of barbarians into western Europe. The effort to assimilate these wild tribes was substantial. They were uneducated, superstitious, and pagan. Learning, science and philosophy declined under the stress.

Towards the end of the first millennium, there was a return of some stability and order that promoted the arts of the scholar. This marks the beginning of a rebirth of learning in the later middle ages. The most important development being the rediscovery of Greek culture and its scientific works. Particularly influential was the rediscovery of Aristotelian philosophy.

Crucial to the understanding of magnetic attraction is the Aristotelian theory of motion. This is not the same as the modern conception. Aristotle conceived of motion as a special case of the category of change. This category was concerned with the alteration of qualities of substances. Qualities were the characters or properties of matter such as hot, cold, wet and dry. Alteration is based on the transformation of the qualities. The transformation is conceived as one of "becoming" which is a form of motion from a potential quality to an actual quality. Hence motion is the process of becoming, something different. In the special case of mechanical motion, which is defined as change of place or locomotion the something different appears to be place. So motion is the transformation of place as a quality.

The nature of the alteration of quality takes place according to its "form" or guiding principal conceived as a cause. Hence, motion or change occurs because the substance is guided by its formal principal during the alteration of its qualities. Expressed biologically, this concept is elegant. The form is contained in the seed of the oak tree. The seed acorn changes or moves towards the form of its design to become an oak tree.

The basic difficulty in this concept is that the limited physics of the Greeks was not able to adequately define the transformations or alterations involved in the process, change of place. This can be seen in the ambiguous use of the ideas used to express the changes. The difficulty can be understood by considering the modern approach to motion. It is known that change of place is not the quality that is directly altered by force during motion. The qualities which are altered are local energy and momentum; change of place occurs as a result of changes in these qualities. Hence, change of place does not involve an alteration of a quality in the Aristotelian sense. The clarification of this is the real breakthrough of the scientific revolution.

The idea that motion is a change of place is the main weakness in the Aristotelian method of analysis. The difficulty arises in the case of projectile motion. In order to conceive change of place as a quality undergoing alteration, there must be a continuous process of alteration; because place is continuously being altered. In the case of the theory of projectile motion, the alteration was based on the idea of circular thrust. Here the idea was that the alteration was a continuous exchange of place, or a Plato says:

”...the various bodies part or come together in the course of mutual interchanges of position and what seems like magic is due to the complication of their effects on each other.”

In the circular thrust, the air moves around from the front of the object to behind it so that the air and object exchange places. Clearly this is alteration of place. It is a process that requires physical contact between the air and the projectile. Hence, the idea is maintained that change of place is altered by some quality which can be seen to cause the alteration. The difficulties arise for the hidden causes of motion due to gravity and magnetic or electric attraction. Here there is no apparent contact to account for the alteration of place.

Given this conclusion, the idea that a mechanical force must be continuously applied by some material contact, which causes the alteration in place, becomes understandable. The problem of the hidden or occult forces of gravity or magnetism is now made clear. These cause a change of place without any apparent cause. This is a challenging problem which consumes much time and effort of philosophers and scholars during the middle ages. The solution that is used is to invoke the idea of form. In the case of natural local motion, the idea of the form, conceived as the goal of the becoming, is invoked to explain that the motion occurs towards its form, which is conceived as its natural place. Thus heavy objects fall towards their natural place because they seek their form. We will see that different concepts are used to account for the cause of motion due to magnetic attraction, depending on the concept of form that is adopted, and that there is clearly a divergence from the ideas of Aristotle, who did not offer a theory of magnetic attraction.

During the middle ages, the interpretation used to give an Aristotelian philosophical explanation of local motion was primarily predicated upon the idea of qualities. The problem was to explain why an iron object acquired a form different from its natural form. Here qualities were invoked to give a form to the iron which changed its natural place. An “active quality” was defined by the principle that the “the mover must be conjoined to the mobile and, except for souls and heavenly intelligences, can move only by being moved.” This was excepted in the case of gravity which had no apparent cause to initiate the downward motion. Because the cause or source of the motion is hidden an “occult quality” was used to explain the downward movement of gravitation. Magnetism was related because it was a second example of an occult force. Iron was seen to be attracted to the magnet without any apparent intervening material cause to initiate the motion. Iron flies towards the loadstone, just as the rock was seen to fall towards the earth. The explanation of the motion of a body towards the center of the earth supposed that it possessed a self activating form which was activated by the presence or “sphere of influence” of the occult source. Hence the magnet’s characteristic occult quality diffused throughout space activates or

excites a power of self movement in the iron which draws or guides it into union with the magnet.⁴

We can see why this is an extension of the older idea of a soul moving the iron. The image of the magnet “loving for iron” and awakening a hidden sympathy is clearly a simpler if less believable concept. The new conception of the middle age scholastic philosophers was more sophisticated, yet the basic principle was unchanged. What the new conceptions sought to explicate was the mode of action that engendered the motion. This was thought to be either an action or quality of the intervening medium or of space itself.

The first approach was developed by Averroes. He employed a concept called the “multiplication of species” to effect the transmission of the magnetic quality through a medium. This is a foreign concept until it is realized that the word “multiplication” should be replaced by “propagation” as used in the modern sense of meaning; to travel progressively. Here the idea of “species” is used in a different way from the modern. Species is used to refer to the different species of qualities (or power or virtue). Each material body was thought to have its own power or species of quality. The magnet possessed the quality that it acted to modify the nature of the substances (it gives them the form whereby they are moved) with which it had contact. The idea was that this acted in a progressive fashion to transmit the magnetic force through the air, then into the iron. Upon reaching the iron a motive virtue was produced causing it to approach the loadstone. According to Averroes, the force that moved the iron was a quality induced in it by the “species magnetica” that went out from the magnet through the medium and altered the iron, thus giving it the power to move itself.

“They say that the magnet alters the air or water that it touches and propagates into the iron a quality which, because of the natural affinity between the iron and the magnet, attracts the iron but nothing else.”⁴

This preserved the principle of Aristotelian dynamics that the motive power must accompany the moving body and accounted for why the magnet acted only upon iron. The magnetic species exerted its effect only upon iron, steel, and other loadstones.

As an example of this type of account of the magnet, consider what Saint Thomas Aquinas writes regarding the motion of the magnet in *Physica* Book VI:

“A thing can in another sense be said to pull, in that it moves (an object) toward itself, by altering it in any way, by which alteration it comes about that the body altered moves with respect to place; and in this way is the loadstone said to draw iron: for as a generant moves heavy things and light in so far as to a place it gives them the form whereby they are moved; so does the loadstone give to the iron some quality through which it is moved to the loadstone.”⁵

Here we see the idea of “form” used in the same manner as the quality, because the quality was believed to depend on the underlying form. A new concept is also present; the idea of alteration. This was the result of the quality acting upon the substance. An example being heat. The action of the quality of heat was to alter the substance and thereby change it. In this manner, the heat as

a primary quality, alters water as substance; turning it into steam. Thus, the explanation says that the quality, magnetic virtue, alters the substance, iron, to give it local motion.

This approach had a significant difficulty. It was unable to explain why the medium was not moved, only the iron. Further, why should the species penetrate any body as medium, while be very specific concerning attraction for iron and other loadstones. This would engender a number of attempts to resolve the difficulty. The main difficulty within the Averroean explanation was the transmission through the medium into the iron. This is clearly difficult to conceive, and was a source of weakness. Hence we see the benefits of the solution proposed by William of Ockham. He argued against the intermediate species or agents; i.e. secondary qualities, that were postulated to avoid having to accept action at a distance, were not necessary to save the appearances. Ockham's solution was elegant, an example of Ockham's razor. He simply declared that there was no reason to object to action at a distance when we can accept it as fact. The magnet, he asserted in his commentary on the Sentences (book 2, question 18),

“pulls [the iron] immediately and not by means of a power existing in some way in the medium or in the iron; therefore the loadstone acts at a distance immediately and not through a medium.”⁶

This solved the problem regarding the medium but left the unanswered question; why are only iron and loadstones subject to the attractive force?

Attempts to solve this problem were not entirely successful. Cardinal de Cusa (Nicholas of Cusa) writes:

”Iron hath in the loadstone a certain principle of its efflux, and while the loadstone by its presence excites the heavy and ponderous iron, the iron is, by a wonderful longing, raised above the natural motion (whereby it ought to tend downward according to its weight), and moves upward uniting in its principle. For were there not in iron some natural foretaste of the loadstone, it would no more move toward that than any other stone; and were there not in the loadstone a stronger inclination toward iron than toward copper, that attraction would not exist.”⁷

Nicholas of Cusa is describing a particular case of local motion where the iron is levitated vertically by the magnet. This is accomplished by exciting within the iron a “wonderful longing” which activates a local motion within it, which raises it up into unity with the magnet. The ideas expressed here are certainly vague, and difficult for the modern reader to understand. This is because the Aristotelian idea of why a heavy body falls is unfamiliar. A body falls because it seeks its natural place. But, in the presence of a magnet, this principle is replaced by a principle which causes the iron to seek union with the magnet as its natural place. The reason that iron only is effected by the magnet is then attributed to a certain unity of principle between the magnet and the iron. Here the idea is that the loadstone and the iron have a certain “sympathy” for one another. This sympathy is stronger for iron than copper. This concept is expressed by the use of “foretaste” and “inclination”. The theory expressed is an elaboration of the Aristotelian idea of a quality causing alteration in the form of a local motion.

One of the most thoroughgoing scholastic descriptions using the Aristotelian approach to magnetism is in the work of Henry of Langenstein, who was born in Hesse Germany in 1325 and

died in 1397. Henry's description of magnetic attraction uses the theory of primary and secondary qualities. A primary quality is an example of a cause of alteration. There are four of them hot, cold, moist, and dry. These however do not exhaust all the possibilities. There exist many secondary qualities as well. The qualities cause alteration; in this case for example local motion. The idea of secondary quality is used to explain why the medium is not effected by propagation through it. Magnetism is interpreted as a secondary quality which does not move the medium.

These ideas require substantial development. A primary quality was considered to be the cause of change or alteration in a substance. In the case of gravity and magnetism the alteration is a local motion. Secondary qualities were used to avoid the difficulty that the medium was not effected by their action. Hence the archetype of a secondary quality is magnetism, because it acted across space causing local motion of iron, without inducing the action in the surrounding air or intervening barriers. In the explanation Henry offers, the magnet acts upon the iron by means of a "sensible active quality" that elicits from the iron the form of local motion. The reason that the magnet acts only on the iron is that other bodies are not properly disposed to receive the peculiar secondary qualities of the magnet. Without this proper disposition, the qualities cannot cause their effects.⁸

A better understanding can be gained by considering the modern approach. The modern opinion is that the magnetic field is responsible for the activation of space by setting up forces in space. How is this substantially different from the Aristotelian viewpoint? If we consider the magnetic field as a secondary quality, and consider the alteration as caused by the force set up by the field, then we can begin to understand what the Aristotelian explanation is trying to accomplish. The concept of a secondary quality is a very primitive and early conception of the magnetic field.

One of the basic disagreements, which is apparent in the explanations, concerns how the secondary quality effects the change in local motion. Saint Thomas and William of Ockham say that the magnet changes the form by pulling, but do not describe how. Nicholas of Cusa says that the magnet acts to change the natural place by a "uniting principle". This may be a way of explaining how the magnet pulls the iron. This is not the same as saying that the magnet levitates the iron by changing its weight, which is discussed later.

Magic and the Magnet In the Middle Ages

The Christian era is inculcated with the principle of revealed truth or knowledge. Truth is to be found in the scriptures; the ancient writings. Truth is not found in the investigation of nature, but in books. The scientific culture is oriented towards seeking the "revealed truth" in books. This explains the renewed interest in the ancient magic books. The translation of the Greek texts into Latin was also accompanied by the translation of the ancient books of magic. The problem with medieval science is that it inherits too much spurious knowledge from the Greek and Roman civilizations, while inheriting no tools or methods to discover or differentiate true from erroneous knowledge. The style of scientific knowledge which is inherited is the knowledge of the scholar who researches ancient books and collects the knowledge of others into large compendiums. No effort was made to verify the reports of others, and there was no standard of proof. The problem with magic is that it is believed to be true knowledge. Legends and myths are passed along as

true and continue without any collaborating evidence. Hence myths and legends survive, as the scholars of the middle ages recover the old books of the Greeks they discover many new false trails. They recover many new arcane and occult magic arts, that had been lost.

The magnet plays an important part in the belief in magic because it serves to prove its existence. The attraction of iron by the magnet served as the standard and unassailable argument of believers in occult and various other marvelous properties. The magnet is the prototype example of an occult action. Since this is a hidden cause, it is possible to invoke many other kinds of hidden causes based on magical beliefs. The proof of them is the magnet.

During this period there was a belief in the occult virtues of gemstones. Here the magnet served as the prime example of a stone with occult virtues. Hence we see that:

”Adamant hard as it is, cracks when heated with goats blood...it counteracts the action of the magnet...The magnet is especially used in the illusions of magic. The great Deendor is said to have used it, realizing that there is no more potent force in magic...”

Indeed Albertus Magnus tells us that:

”the cause of the virtue in stones is indeed occult since we see the magnet attract iron and the adamant restrict that virtue in the magnet.”

This demonstrates one of the most persistent erroneous beliefs; the myth that the adamant, thought to be diamond, would cancel the magnets attractive property. Another myth was the marvelous mill operated by the occult virtue of the adamant. This being a perpetual motion machine. These demonstrate the persistence of a belief in magic.⁹

One of the most persistent ideas is that a magnet rubbed by garlic loses its attraction for iron. This is stated by Plutarch who tells us that:

”if light objects are oiled, amber fails to attract them as usual; and iron rubbed with garlic does not respond to the magnet.”⁹

There may be a germ of truth here, because amber loses its attractive power when oiled and this may be true for objects it attracts. But it is not true for the magnet rubbed by garlic. This idea gains credibility from the theory of the emanations. Oiling the objects would tend to prevent the pores in them from being opened by the magnet; thereby blocking the effluences. Hence, its ability to attract would be impeded. William Gilbert scoffs at the credulity of others who believed this tale. He performs a simple experiment and disproves it.

But why did this magical myth survive the era of medieval science. One answer is given by Henry of Langenstein. Henry accepts the common belief that garlic has the power to impede the action of a magnet. But why didn't Henry test this? One reason was that he believed that there existed occult powers that were opposed or antithetical to a given power. The garlic possessed a quality which opposed the magnetic quality. Hence the idea fit a preconceived notion. The idea of an experiment was fraught with problems. The experiment might be faulty for any number of

reasons: the garlic was not prepared properly, it was not fresh, and the magnet was not properly rubbed. Hence, an experiment could not disprove the assertion, because it could always be argued that something had gone wrong with the experiment.⁸

During the middle ages experimental proof was an alien idea. Belief in magic was so strong that a rational disproof appeared fruitless. This is a reasonable explanation to account for the failure to use experiment. Peter Peregrinus had used it to demonstrate the nature of the magnet, but his results did not involve controversy. They supported magical belief. He used them to prove that the magnet drew its power from the stars and that a perpetual motion machine could be built. The idea of magic was very strong. There were many believers among the clergy and scholars. Proof by demonstration was a new idea. It was not an important methodological tool of proof. Employing a proof by demonstration was mainly used to support a strong argument involving an entrenched belief. Hence a proof by experiment that a magnet rubbed by garlic loses its power would be a readily accepted demonstration, but a negative result would not have the compelling power that it has today. There were many ways to explain away the negative result. Belief was not subject to rational disproof by experiment. Remember that for the middle ages, proof by experiment was of little weight, what counted was the authority of ancient testimony. This explains the persistence of magical beliefs in the middle ages.

On Sympathy and Antipathy

The magical principle of sympathy establishes a duality between the subject and object of the sympathy. This is an old idea that was established before the rise of philosophy in Greece. The idea of antipathy extends this principle of duality to include the opposite or contrary of sympathy, or antipathy. This is an old idea as well. We see it in the ideas of Empedocles where the fundamental forces are love and hate, hot and cold, moist and dry. In book XX of Pliny's Natural History, the powers of sympathy and antipathy for the loadstone are discussed as follows:

” In matters relating to the fundamental principles of things the Greeks have employed the terms ‘sympathy’ and ‘antipathy’, as, for example, in the cases of water putting out fire, the sun swallowing up water, or the moon generating water. The sun and moon are eclipsed, each through the transgression of the other. To turn from heavenly things, magnetite attracts iron while another type of stone repels it.”¹⁰

This fragment tells us that the idea of the attraction and repulsion being related to sympathy and antipathy was so strong that it led to a belief in a type of repelling magnet even though no such stone existed. Over the years, many claims of the existence of this type of magnet were recorded in the literature, but never proved.

The magnet was frequently cited as an example of sympathy and antipathy. The magnet was occasionally mentioned within the context of poisons, and their actions. Poison was interpreted as an antipathy just as the magnet acted by a sympathy for the iron. “The magnet attracts iron by sympathy and poison kills by antipathy.”¹⁰

During the 12th century, the idea of sympathies was used by Alexander Neckham (1157-1217AD), an English Augustinian monk, to explain the forces of attraction and repulsion. He used the concepts of similitudes and dissimilitudes. These were used to explain the operation of attractive force. Neckham is known to have performed experiments on the attraction of gems other than amber. He discovered that the gemstone jet, was capable of attracting when rubbed just as amber:

”If you ask its value as ornament, jet is black and brilliant; if its nature, water burns it and it is extinguished by oil; if its power, being heated by rubbing, it holds things applied to it, like amber; if its use, it is an excellent remedy for dropsy.”

Neckham believed that while chaff was attracted to amber or jet, the opposite or contrary was not true. Hence chaff did not attract amber or jet. Similarly, iron was attracted to a loadstone, hence the iron was moved, but the reverse was false; iron does not move the loadstone. This requires an explanation. Neckham used the doctrine that the attracting objects act more strongly, than the attracted object. This was required because of the following peculiar conception. According to the prevailing principles of mechanics, it was believed that if the attractive force of the two were equal, that they would counterbalance; the resultant being zero force, and no motion would result. Hence in order to cause motion the objects had different degrees of similitude.¹¹

Neckham’s other great contribution was his description of the compass; the first extant European description. This is considered the first certain knowledge of the use of the compass. His book, *De Naturis Rerum* (On The Natural World) gave the following description:

“Mariners at sea, when, through cloudy weather in the day, which hides the sun, or through the darkness of the night, they lose the knowledge of the quarter of the world to which they are sailing, touch a needle with a magnet which will turn around until, on its own motion ceasing, its point will be directed toward the North.”¹²

Here we see a very important aspect of the power of sympathy, a power which directed the needle touched by loadstone to always point towards the north.

Peter Peregrinus’ in his *Letter On the Magnet* written in 1269 AD borrowed Neckham’s idea and applied it to magnetism. Peregrinus’ theory of magnetic attraction was similar to the idea of similitudes and dissimilitudes. He uses the terms agent and patient:

“But the Northern part of the stone attracts the Southern, and conversely, as has been said, and in its attraction, the stone of stronger virtue is active, whilst that of the weaker is passive. But the cause of this thing I now think is indicated in this way: the agent strives not only to join its patient to itself, but also to unite; so that out of agent and patient, there may, according to nature, be made one.”

The idea that the stronger virtue becomes an active agent and the weaker passive a patient, implies a form of sympathy between the poles. Peregrinus does not elaborate on this sympathy. He goes on to discuss the unity of a loadstone that has been cut in half and separated into two parts and then joined again by their mutual attraction; i.e. opposite poles together:

“But if the same parts be brought near one another again, the one attracts the other until they are joined...whilst as far as the natural appetite is concerned, they will make one body as at first...Therefore, the agent, as you see by the experiment, strives to unite its patient to itself, but this is done by reason of the similitude between them...For in this union there is retained or preserved the identity of the extreme parts, in the likeness in which they were at first...But if it were done otherwise, this identity or similitude of the parts would not be preserved.”

Peregrinus then proceeds to discuss the case when the parts are joined in the opposite manner; i.e. like poles together:

”But if it were done otherwise, this identity or similitude of the parts would not be preserved...Lo, the former identity or likeness is dissipated...And so here neither identity nor similitude is preserved. For that, which has now been converted out of two into one, must be in the same species as the agent, which would not be so, if nature were to choose that impossible arrangement...For nature tends towards being, or acts in the better way in which it can: it chooses first the first order of action or of method in which the identity is better preserved than in the second. It is clear therefrom from these considerations, why the South attracts the North and conversely. But South never naturally attracts South, nor North.”(spThompson trans)

Peregrinus idea of sympathy is not magical. For him it is a result of a rational natural process.

The discovery of the compass and its technical development and widespread use by the 14th century led to a widespread knowledge that the magnetic needle always points to the north star. The result was a widespread belief in the astrological influence of stars as the cause. We see this in the “Paradiso” a poem by the celebrated Italian poet Dante, a passage alludes to the mariners compass:

”Then from the heart of one of the new lights,
There came a voice, and as I turned toward it
I seemed a needle Turning toward the pole star.”

The sentiment expressed here is reminiscent of the passage from Plato’s Ion. There the poet Ion and his audience are inspired by the divine just as the magnet inspires iron rings to hang from it. Here the passage says that the beauty of the heavens inspires the poet just as the compass derives its power to give direction from a sympathy with the stars.

But there was also a different kind of sympathy that could explain the action of the compass. As Neckham explains, “the magnet is touched by a needle,” an action by which the power of the magnet passes into the needle. The procedure has a magical aspect, because the needle acquires the magnetic power and acts as the magnet does. The power of sympathy passes from the loadstone into the needle. This power being in the needle causes it to be united with distant loadstones which being in the north, causes the needle to point towards them. This alternative explanation first appears in a poem, written by Guido Guinicelli around 1250AD. The following passage explains that the directive power of the compass is caused as follows:

”In those parts under foreign skys
Are the mountains of loadstone
Which give power to the air
To attract iron, but, because distant,
It requires to have assistance from similar stones,
To bring it into use, And direct the needle towards the star.”

The verses tell us that the source of the virtue is the magnetic mountains in the north. The virtue is propagated by the air. But, the air is insufficient alone over long distance and therefore loadstones contained in the earth are required to provide assistance. This poetic explanation is remarkably similar to the one advanced nearly 350 years later by William Gilbert. It invokes a sympathy with magnetic mountains in the north as the primary cause, but also it invokes the sympathy of the earth itself in order to account for the propagation of the virtue over a large distance.

A second part of the poem reads:

“The learned relate that the loadstone
Could not attract
Iron by its power,
Were it not that the air between them aids;
Although the calamite is a stone, the other existing stones
Are not so powerful
To attract, because they have not the influence.” (Mottelay page 44)

This second stanza, which follows the one above, is a poetic rendition of magnetic attraction for iron. It tells us that the attractive power is derived from the air, and that only iron is attracted because other stones do not have the correct sympathy. The author of these verses appears to realize that if the air theory is correct, the distance involved is so great that some additional action must be present, which he attributes to the presence of loadstones in the earth. But, this also requires to explain why the common rocks of the earth do not exhibit a magnetic attraction for iron.

In his book, *De Magnete*, William Gilbert derisively relates to us the sundry and various explanations for the sympathy of the magnet which accounted for its directive power.

“All these philosophers, our predecessors, discoursing of attraction on the basis of a few vague and indecisive experiments and of reasoning from the recondite causes of things; and reckoning among the causes of the direction of the magnet, a region of the sky, celestial poles, stars, asterisms; or mountains, cliffs, vacant space, atoms, attractional or collimational regions beyond the heavens, and other like unproved paradoxes, are world-wide astray from the truth and are blindly wandering.”¹³

Gilbert’s derision of these explanations shows that they were not based on rational investigation but on speculation as we see in the following examples. Marcilius Ficinus believed that the compass pointed north because of the constellation Ursa Major:

”In the loadstone, the potency of Ursa prevails, and hence it is transferred into the iron.”¹³

Paracelsus believed that stars were magnetic and were attracted to iron. Gilbert says that:

”Fernel in his book, *De abditis rerum causis* , says that in the loadstone is a hidden and abstruse cause; elsewhere he says this cause is celestial, and he does but explain the unknown by the more unknown.”¹³

We see in these examples, that the underlying cause must be some form of sympathy, or antipathy between the magnetized needle and the primary cause, usually thought to be in the heavens. This certainly required a power of sympathy, because the materialist theory regarding the motion of air caused by emanations creating a vacuum was simply not believable. Once it was realized that the magnet was drawn to the north-south direction, by some hidden force in the heavens, or by some huge magnetic mountain range, the distance through which this action was exerted was simply too vast to be accommodated by the materialist theory. The entire earth would have to be sucked up into the heavens by the vacuum or drawn into the mountain range. This explains why materialistic theories fade into the background during the middle ages, and are replaced by immaterialistic ones employing the idea of sympathy.

During the 16th century the idea of sympathy was employed by Gerolamo Fracastoro to explain electricity and magnetism in a new way. Fracastoro, in addition to discovering that diamond is an electric substance like amber, noticed that the application of the idea of sympathy to electric attraction faced the difficulty that the substances, which were attracted were very disparate and exhibited no obvious similarities. Further, there were different substances that exhibited the effect; amber, jet, and diamond. He concluded from his experiments that:

”...perhaps hairs and twigs are drawn to amber and diamond not because they are hairs, but because there is imprisoned within them either air or some other principle that is first attracted and that has reference and analogy to that which of itself attracts; and herein amber and diamond are as one, in virtue of a principle common to both.”¹¹

Fracastoro’s hypothesis was designed to save the principle of sympathy and antipathy, by asserting that there was a common sympathy between the hidden principles inside the objects which exhibit the electrical attraction. This common principle is not absurd. Modern theory also uses this concept. It supposes that all materials are made up of atoms and molecules which exhibit electric polarization. Hence the objects subject to electrical attraction are made up with or contain the same basic principle of atomic structure.

The philosophy of sympathy and antipathy as used by Fracastoro was formally Aristotelian. It was based on the continuity of nature, avoidance of a vacuum, the motion of elements towards their natural places, the attraction of like for like, and the mutual repulsion of contraries. His theory of sympathy was described as follows in a quotation from *De sympathia et antipathia rerum*, written in 1546:

“When two parts of the same whole are separated from each other, each sends toward the other an emanation of its substantial form, a species propagated into intervening space; by the contact of this species each of its parts tends towards the other in order to be

united in one single whole; this is the way to explain the mutual attraction of like to like, the sympathy of iron for the magnet being a typical example.” (Concepts of Force p. 73)

He rejected the idea that the magnet turned toward the pole star because of a sympathy with the pole because of a primary quality. A primary quality was corporeal and manifest and had the effect of radically altering the medium. Hence a secondary, hidden or spiritual quality was needed. Therefore, he asserted that the turning of the compass needle toward the poles was due to the existence of magnetic mountains of iron at the north pole. Frascatoro asserted that the magnetic force must be a spiritual or immaterial form as opposed to a material one because the propagation of this species required that it travel a vast distance from the magnetic mountains at the north pole. He asserted that a corporeal or material species could not possibly be disseminated over such a great distance, hence the species must be spiritual.¹⁴

Frascatoro applied this approach to magnetism in the following way. He supposed that when the principles in the magnetic substances were analogous, an attraction would result; conversely when the principles were contrary, the result would be a repulsive force. A year after Frascatoro published his results, a book written by Marcellus Empiricus during the fourth century A.D. titled, De Medicamentis was published which reported “that a magnet called the antiphysion attracts and repulses iron.”* The persistent reports of the existence of this variety of magnet may have led Frascatoro to his idea of sympathy and antipathy.

Frascatoro’s theory had the unfortunate flaw that no definitive case of magnetic repulsion, or of the antiphysion was definitely proved. Gilbert uses this criticism in the following way:

“As for Frascatorio’s belief that a loadstone may be found that shall repel iron, in virtue of some principle latent in it that is opposed to iron, it is without any foundation.”¹⁵

Although no loadstone has been found with this property, materials which are repelled by a magnet were discovered by Michael Faraday in the 19th century; he gave to materials with this property, the name diamagnetic. Today we know that most materials are diamagnetic and that they are repelled by the magnet. The effect is very weak, and extremely intense fields are required in order to reveal it. However, small objects and animals such as insects and frogs have been levitated in some very intense magnetic fields.

The idea of sympathy and antipathy has the obvious application to the explanation of the repulsion and attraction of magnetic poles. We saw above that Peter Peregrinus used a similar idea to explain the attraction and repulsion between poles of a magnet. This does not seem to have been otherwise considered before Gilbert. In book two, chapter 39, of his treatise “On the Magnet”, Gilbert discusses mutually repellent bodies as follows:

“They tell us that as like things attract for conservations sake, so unlike things and opposites repel and drive each other away, as is seen in the antiperstasis (counteraction) of many bodies; but is most potent in plants and animals, which as they attract things in affinity and of kin, so do put away things extreme and disadvantageous to themselves.”

He is critical of this but says regarding loadstones:

“Now a loadstone does repel another loadstone; for the pole of one is repelled by the pole of another that does not agree naturally with it; driving it, it makes it turn round so that they may come together perfectly according to nature. But if a weak loadstone floating freely in water cannot, on account of obstacles, readily turn about, then it is repelled and driven farther away by the other. All electrics attract objects of every kind; they never repel or propel.”¹⁶

Although Gilbert does not embrace the idea of magnetic sympathy to explain magnetic attraction by poles, it is a major advantage for the immaterialist theories. The materialistic theories have the difficulty of accounting for the contrary attractions and repulsions present within the same loadstones. The attraction changing into repulsion merely by turning around the magnet and presenting the opposing pole. The emanation theory was not able to account for this basic observable fact of magnetism. The primary problem was that the theory used air to effect the attraction. After expelling the air between the magnet and iron, the resulting void drew them together. Since this action only works in one direction, the theory could not explain repulsion.

Astrology and the Influence of the Stars

Interest in astrology had a strong and vital rebirth during the middle ages. There was a strong association with the magnet and magnetism for two reasons. The magnetic attraction for iron, an effect that was well known and easily demonstrated, was often cited as an example of an occult influence that would be exerted at a distance. The second reason was the obvious ability of this magnetic influence to turn the compass needle into alignment with the heavens. In a book titled “Introduction to Astrology”, Michael Scot explains that: “...the stars are only signs, not causes, and that their influence on inferior creation may be compared to the action of the magnet upon iron...”²⁰

It is surprising to discover that astrology in western europe was derived from Plato and the Neo-Platonic tradition. Plato believed that :

“the sky is the seed bed or cradle of forms, and that from it come more secret and hidden powers and forces which are to be found in all things.”

For the people of the later middle ages, one of the mysterious powers emanating from the stars was clearly the hidden force which directed the compass needle.²⁰

One of the great names in the history of Arabic learning in the ninth century is Alkindi. He lived under Mohammedan rule and wrote in Arabic. He translated the works of Aristotle and other Greeks into Arabic and wrote many original works of philosophy, politics, mathematics, medicine, music, astronomy and astrology. His work tended to mix up the ideas of science and superstition in his enthusiasm for the pursuit of knowledge. In his book The Theory of the Magic Art or On Stellar Rays Alkindi describes his belief in the radiation of occult force from the stars. Each star having its own peculiar power or force and certain objects under its influence. However, the stars were not the only objects which emit rays; all objects in nature have their own peculiar radiation. The sages were presumed to know of a more occult interaction of remote

objects suggested by the power of the magnet and the reflection of an image in a mirror. All such emanations are caused by celestial harmony, which is revealed by the close study of the hidden secrets of nature. Alkindi is an example of a thinker who is unaware of the difference between science and superstition.²¹

Duns Scotus, a famous theologian and scholastic philosopher of the early fourteenth century was influenced by both Aristotle and astrology. Scotus believed that

”knowledge obtained through the senses and by experimental verification of the natural existence of things is the basis and source of all other knowledge.”

Scotus is an example of the curious mixture of beliefs typical of the period. He accepted the concept of occult virtue and recognized astrology and alchemy as reputable sciences. Scotus believed that the sky acts in the terrestrial realm. The stars act upon the inferior elements, earth and water, and effect alteration and generation. The stars were held to cause the motion of the inferior elements:

”when the sun and other hot planets are in the zenith of any region, the superior elements, fire and air, are augmented, and the inferior elements, earth and water, are diminished and converted into air and fire...The moon exerts an attraction on the tides like that of the magnet on iron.”

Scotus goes on to tell us that these occult forces act on animate beings as well as the inanimate. They may also disorder the senses and affect the intellect, as is evidenced by the insane and lunatics, whose imagination is confused. Here we see that an occult force, as demonstrated by the action of the magnet, is likened to the action of the moon on sanity. This may explain why the occult actions of the magnet and the electric shock of the torpedo were used in attempts to cure insanity. They were used to counteract the occult forces believed to be causing the insanity.²²

Another surprise is the association of Thomas Aquinas with astrology. He saw the magnetic attraction as the chief example of the existence of a natural occult virtue as opposed to the action of demons; conceived as illicit magic. Hence the magnet was natural “one of the occult works of nature”. Natural objects acted in accordance with the properties of their component elements. These actions were manifest; although the cause was not. The magnet being the first example in importance. Surprisingly, Aquinas explained the existence of such occult virtues by the influence of the heavenly bodies upon the world of nature, and attributed the wonderful power of precious stones to “a certain celestial and occult virtue.”²³

Aquinas opposed the idea that demons were responsible for natural actions. Ironically, this concept also used magnetism as its justification. William of Auvergne tells us that demons can toss sticks and stones about. He explains that this is no more strange than the ability of the magnet to attract iron.²⁴ Here we see that the occult virtue of the magnet is used to justify the existence of demons. A result that is surprising. But we must remember that the reason for the magnetic action was a mystery. Being unexplained, although manifest, it could be used to justify all manner of spurious conceptions, which attributed naturally occurring phenomena to hidden forces. William also applied this idea to the cause of the tides. In his work *De Universo*, he

compared the action of the moon upon the waters of the sea to the attraction of the magnet for iron. William clearly saw how the idea of magnetic attraction could be used to explain other kinds of occult action, gravity being one of them.

Mystical astrological explanations were not the only form of explanation to account for the north-south orientation of the compass. In 1549 Fortunius Affaydatus published a book dedicated to pope Paul III. Titled "Physical and Astronomical Considerations". The book has an astrological orientation; dealing mainly with human physiology and psychology and the influence of the stars. Affaydatus explains why the celestial pole attracts the magnet to itself. He explains that the earth seeks the center of the universe in order to avoid and flee from the circular motion of the heavens. For the same reason the magnet, moving north and south instead of parallel to the equator, seeks the poles which are immobile. Hence, the compass needle is attracted to the poles of heaven because they are stationary. His proof is explained as follows. The magnet needle turns toward the north pole rather than to the pole star. Below the equator the compass points to the south pole. Hence the needle is not attracted by the pole star in the tail of the constellation Ursa Minor. Affaytatus explanation of magnetic attraction, is that like attracts like and that neither iron nor the magnet could indulge in its peculiar tendency to move towards the poles without the other. Hence he interprets the magnetic attraction as a mutual action between both magnet and iron.²⁵ The explanation is not very convincing. Gilbert calls it "silly philosophizing".

Opponents Of Astrology and Magic

In the previous sections the proponents of the idea of astrological influence and occult magical influences have been presented. During the later half of the fourteenth century there was a concerted effort in opposition to astrology. Nicolas Oresme bishop of Lisieux was the first to lead the attack. He published a number of works in opposition to astrological beliefs giving numerous reasons why they were false. In particular Oresme argued against the idea that human destiny was controlled by the stars and planets.²⁶

One of the pillars of support for astrology and magic was the attraction of the magnet for iron. Henry of Langenstein developed and presented at least three different arguments in an attempt to discredit this idea. The result was his theory of the magnet based on secondary qualities which was presented in the section on the Aristotelian explanation of the magnet. Henry's approach to the problem was to argue that the idea of an occult virtue in the magnet was mistaken, and it was incorrect to present the magnet as an example of an occult force.

Henry adopts the same attitude as Oresme. Explaining natural phenomena by ordinary causes and processes of nature, and in terms of the four primary qualities and elements, without recourse to occult virtues, marvelous explanations, far fetched celestial influences, and the activity of demons. Henry's reasoning was to present the explanation of the magnetic attraction within the context of known active forces. The basic idea was that magnetic attraction is simply an ordinary process of nature, which operates by the known principles of explanation. In a second approach which we met in the discussion of the effect of garlic rubbed on the magnet, Henry argues that as an ordinary force of nature, it is easily contravened by the action of other

ordinary natural substances such as garlic and adamant. Hence there is nothing marvelous or occult in the action of the magnet.

The third argument presented in his On the Reduction of Effects to Their Common Causes was peculiar. He held that the four primary qualities and their derivatives were sufficient to account for all natural phenomena including those attributed to occult virtues in the stars and the magnet. He asserted that the magnet did not exert an attractive force on the iron. Since this seemed self evident, Henry argued that the magnetic force upon the iron was apparent and not real.

“The iron is so disposed qualitatively to the common harmony of nature and to the sensible active qualities of the magnet, that there is deduced from the potentiality of the matter of the iron a quality which moves the iron locally.”

Henry then goes on to support this assertion by using the argument that the iron levitates itself in the presence of the magnet. Here Henry is saying that the magnet merely activates a quality already present in the iron. The main point is that the magnet doesn't exert a force to move the iron, that property exists within the iron itself.

“Some say that the magnet with the iron suspended from it weighs no more than alone...For if I take a stone in my hand, my weight is increased that much, but if the stone lifted itself to my hand, I would weigh no more.”

Henry's assertion is that the iron possesses a quality of local motion which acts to lift itself. This is a peculiar notion. It is founded on incorrect physical principles. However, it did fit the job of arguing that the magnet did not lift the iron via its occult virtue of attraction.²⁷

The argument here is similar to the explanation presented by Nicholas of Cusa. The peculiar aspect is the idea that the iron levitates itself. Here there is another idea present; that the magnet acts by counteracting the quality of heaviness in iron. Gilbert describes this as an example of “the errors and impotent reasoning” of his predecessors:

“...iron held by a loadstones' attraction, being placed in a balance, adds nought to the weight of the loadstone, as though the weight of the iron were absorbed by the virtue of the loadstone.”

This seems to be a case of considering only one manifestation of the magnetic power. The ability to suspend iron objects in opposition to the force of gravity. It neglects another attractive power, that of making the iron follow the horizontal movement of the magnet, such as described by Saint Augustine's experiment of the silver plate. There are at least three different explanations which can be entertained: The magnet pulls the iron by changing the natural place, the magnet pulls the iron by a principle of unity with the magnet, and the magnet levitates the iron by contravening its heaviness. These ideas are not necessarily distinct, because we see that they tend to merge together, as in the case of Nicholas of Cusa.

The Rise of Natural Magic and Pseudo-science

The rise of natural magic is a description of the change in fashion or viewpoint that takes place in electrical and magnetic science during the renaissance. Here the term natural magic is used in the sense of the 17th century. It refers to the use of natural phenomena to perform or explain the inconceivable. It represents the shift in fashion from the Aristotelian mode of interpretation of electricity and magnetism. Plutarch's explanations of electricity and magnetism in the 1st century A.D. is evidence that this was the primarily accepted theory during the Roman period. The first evidence of the shift to natural magic is found in the work of Saint Augustine, which we discussed previously. He describes the phenomena of magnetism and electricity within the context of natural miracles. Many of the phenomena that Augustine discussed in this category were clearly "magical myths and legends", but electricity and magnetism have survived as real natural phenomena.

During the renaissance there was a movement, Paracelsus being the most well-known, to overturn the conservative traditionalism dominant in the universities. This represented an all out attack on heathen Aristotelian philosophy depicted as inconsistent with Christian philosophy. It is ironic that their program would replace this with a Christian neo-Platonism and Hermetic philosophy which is also derived from the pagan roots of ancient Greece. They held there were two sources for the truth: the book of divine revelation, the scriptures, and the book of divine creation, nature. This resulted in a call for a new philosophy of nature based on observation and experiment as a way to reveal the truth of the divine Creator in nature. Another proponent of this view was Bapiste Porta. He defined natural magic as the survey of the whole course of nature. Hence natural magic was an attempt to unify nature and religion in a way conceived as the most perfect of worldly knowledge.

During the renaissance an important development occurred, which is a source of confusion in the history of science; the rise of pseudo-science. There was as a result of the development in humanist thinking a parallel development of mysticism and magic that had been long opposed by the Catholic Church. This rise in magical beliefs became closely associated with magnetism because it was a tangible form of natural action that became the model for the new beliefs. This model was used to explain all manner of phenomena. Since magnetism had for centuries been associated with magical legends and superstitions, its credibility as a real phenomenon, led credence to many innovative but erroneous ideas. The main thrust of this movement was to challenge the accepted ideas of the church which sanctioned the Aristotelian theories. This was to be achieved by resurrecting the old knowledge; much of which was magical and astrological in nature.

It provoked a strong reaction from the church which implemented the inquisition to suppress the most disgusting aspects of the movement. After attempts were made to assassinate the pope using black magic, the efforts of the inquisition intensified. During the middle ages there was an increasing fascination with the magic arts, as we have seen. This culminated at the end of the fifteenth century in a tragic episode. The paranoid church launched a major effort to suppress witchcraft. This occurred at a time when religious turmoil and disaffection was mounting. The church and its institutions were threatened. It challenged the prevailing Aristotelian philosophy of explanation.

During this period there is a return to the materialist explanation of the magnet. Bapiste Porta published a famous series of books titled Natural Magic. In the book considering magnetism, Porta explains that the magnetic attraction is caused by minute particles of loadstone:

”Concentrated as it were into hairs, and springing from friction of the loadstone, which parts fastening on to the iron give it the magnetic powers.”

A similar idea is present in an explanation offered by Cornelius Gemma, who lived from 1535 to 1579. In Cosomocrit X he ”declares that loadstone draws iron to itself by means of invisible rods.” These are clearly rudimentary attempts to supplant the dominant Aristotelian explanation of the period.

At this time there is also a primitive movement towards experiment, which is associated with natural magic. Cardan and Bapistse Porta both perform experiments to verify that a magnet rubbed with garlic fails to attract iron. They both found the attraction was unaffected and disproved the garlic story. Porta tested whether diamond contravened the magnetic attraction and proved that it did not.” It is false that the diamond doth hinder the loadstone’s virtue.” Porta describes his investigations of the effect of garlic on the magnet in the following entertaining manner:

”It is a common opinion among seamen that onions and garlic are at odds with the loadstone; and steersmen and such as tend the mariners card are forbidden to eat onions or garlic lest they make the index of the poles drunk. But when I tried all these things, I found them to be false; for not only breathing and belching upon the loadstone after eating of garlic did not stop its virtues; but when it was all anointed over with the juice of garlic it did perform its office as well as if it had never been touched with it, and I could observe almost not the least difference...And again, when I enquired of mariners whether it were so, that they were forbidden to eat onions and garlic for that reason, they said they are old wive’s fables and things ridiculous, and that seamen would sooner lose their lives than abstain from eating onions and garlic.”

There was also a primitive beginning towards quantitative measurement. Porta performed an experiment to see if a loadstone drew nutriment from iron, by storing a loadstone in iron filings, and then weighing it. He found that there was a small increase in weight of the loadstone. Gilbert says that this increase was not definitive and proved nothing:

“But iron is not attracted by the loadstone, as Cardan and Alexander Aphrodisius supposed, so that it may be nourished with morsels of it ; neither does the loadstone gain strength from iron fillings as from a nutritious food. Bapista Porta, having his doubts about this view, and wishing to make an experiment, took a loadstone of determinate weight and buried it in iron fillings of a weight not unknown; and after he had left it there many months, he found the stone heavier, the fillings lighter. But the difference was so minute that Porta was uncertain as to the truth. This experiment of Porta’s does not prove that the stone devours anything, nor does it show any process of nutrition, for minute quantities of fillings are easily lost by handling.”

Both Porta and Cardan used weighing to measure the strength of a loadstone, a method which Gilbert later adopts.

The Separation of Electricity and Magnetism

In traditional histories of electricity and magnetism, William Gilbert is credited with separating electricity from magnetism on the basis of his experiments which showed that they were significantly different phenomena. This distinction was not original with Gilbert. The rise of natural magic created a clear separation between magnetism, which became increasing associated with natural magic, and electricity which showed clear differences.

The difference was clearly recognized by Plutarch at the beginning of the period. Over time the differences became more pronounced as the evidence accumulated. Magnetism was seen as the prototype of an immaterial occult force, while electric attraction continued to be attributed to an unseen material exhalation which moved the air. The electrical attraction lacked contraries, there were no poles and no repulsion; both of which were present in magnetism. Magnetism was restricted to a particular species, iron. But, electricity was not limited to a particular species so the ideas of sympathy and contraries could not be applied to it.

Up until the 13th century, the explanations for electricity and magnetism were based upon the same principles and conceptual approach. This was only natural because both phenomena were attractive actions resulting in a motion of the attracted object towards the attractor. If the magnetic explanation was material, then the electric explanation was as well. The first important difference appeared in a book by an anonymous author and was entitled “Summa philosophiae”. The author, who is unknown, offered two different explanations for electricity and magnetism, an innovation that would be the basis of Gilbert’s later approach. Magnetic attraction was contrasted with electric. Magnetism was attributed to the action of the “Aristotelian form” and electricity was attributed to “a more elementary virtue”. Clearly, the author saw a significant difference and sought to elucidate it by using different modes of explanation for their attractive actions.¹⁹

During the renaissance some critically important experiments were announced which enhanced the divergence. Marsilio Ficino, who is best known for his reintroduction of Platonic form theory, performed an important experiment. He attempted to determine if the electric attraction was directional. The details of the experiment were not described. Ficino announced only his result, which was that rubbed amber did not align with the poles of heaven.³ Here was a really significant difference that pointed to completely different modes of action for electricity and magnetism. Magnetism became more strongly associated with some action of sympathy with the poles of heaven, while electricity was not. The result was a growing difference in interpretation.

We have already seen that diamond and jet were found to be electric substances in addition to amber. But, there was no agreement that electricity and magnetism were different up to the publication of De Subtilitate by Jerome Cardan in 1551. Cardan performed a careful study and arrived at the definitive and unqualified conclusion that: “the magnet stone and amber do not attract in the same way”. Cardan found that electricity and magnetism differed in quality and not merely in degree. He enumerated the evidence as follows:³

The amber draws everything that is light; the magnet iron only.

The amber does not move chaff toward itself when something is interposed; the attraction of the magnet for iron is not similarly hindered.

The amber is not mutually attracted by the chaff; the magnet is drawn by the iron.

The amber does not attract at the end [does not exhibit polarity]; the magnet attracts the iron sometimes at the north and sometimes at the south.

The attraction of the amber is greatly aided by heat and friction; that of the magnet by cleaning the attracting part {thus removing foreign matter and scale}.

By 1600 when Gilbert's book, *On the Magnet*, is published, there is a clear difference in interpretation of the magnetic attraction from that of amber. The magnetic attraction is attributed to an immaterial or occult virtue, following the Aristotelian theory of the multiplication of the species and qualities, while the electric attraction of amber is attributed to a material effluvia.

Retrospective View of the Christian Era

Looking over the Christian era the basic theme is a shift of emphasis from a materialistic interpretation to an immaterialistic or "field" viewpoint. Here the field conception is very primitive. There is an appreciation that the attractive action of the magnet for iron does not involve a form of action where local motion is induced by material contact. The Platonic idea of the circular thrust, which implies action by the air to cause motion loses its force. We see that it is last mentioned in the poem by Gunicelli around 1250. At about this same time, the Aristotelian theory of qualities is developing. It clearly has the advantage of being better fitted to the facts, but its vagueness was a disadvantage. The primary problem is the lack of understanding of mechanical motion. Since this science is still in its infancy, we can not expect that theories of magnetic attraction will be founded on correct mechanical principles.

The most significant development of the Christian era was the discovery that the loadstone was directed by an unknown force to align with the poles of the heavens. This discovery and the technical development of the compass is the main development of the period; this causes a significant shift in interpretation. It requires a new paradigm. How to account for the mysterious effect on the compass needle. There were two mysteries. First, what was the source of the mysterious power that caused the loadstone to align itself with the poles of the heavens. A second mystery was; how did the loadstone convey this power to an iron needle merely by touching or rubbing a loadstone? When viewed from this perspective, we can understand that the compass originated in the practice of magic and then evolved into a navigational instrument. Consider the description of the compass and its early use. The needle was placed in a bowl of water and then whirled around in a circle. A procedure that suggests magic.¹⁸

The growing interpretations based on magical principles provide a real impetus for the development of a rational theory of magnetic attraction. The problem was that the occult theories based on magical principles are not distinguishable from the rational view of the Aristotelians. In both cases an unseen power is invoked. In the magical case, the power is magical, because it derives the motive power from magical principles. There are many types of these. Power derived from sympathetic magic, was used to explain the attraction for iron, and astrological rays from the stars Aristotelian theory. Towards the end of the period and during the renaissance, there is a

rejection of the theories of Aristotle and the resulting search for an alternative led to a rising interest in the astrological and sympathetic magic interpretations. There was also a resurgence in the materialistic theories which were returning to favor at the end of the period.

Historians of science have traditionally tended to interpret the rational attempts of the Aristotelians such as Henry of Langenstein with the animistic, magical, and mythological beliefs of the period. This is particularly true during the renaissance, when the magical beliefs gain Aristotelians. There is not much difference between a magical occult power and a secondary quality, both are unseen hidden forces which act at a distance without physical contact.

The rise of natural magic and its reaction against Aristotelian rationalism is a complicating factor. It is really a precursor to the inductive science of the 17th century. But, this connection is obscure. The ideas of natural magic remained non-rational but their use of the experimental method gave the movement a rational foundation that opened the path towards modern science.

The problem for the philosophers of this period was that there were many different ways to interpret the apparently magical actions of the magnet. Saint Augustine recognized the apparent wonderful effects but insisted that the explanation was a rational act of nature. As the period progressed, the irrational ideas of magic and astrology gained ground. The discovery of the compass with its mysterious ability to always point north only strengthened the magical interpretations of magnetic action. Towards the end of the period, we see that rational explanations of nature are losing ground and a concerted effort to suppress the myths and false superstitions was undertaken by the inquisition.

The situation regarding electrical attraction is simpler. Not much progress is made. The period does not reflect any serious attempts to develop a theory of electrical attraction. It presents difficulties for both approaches. As the period progresses the differences between electrical attraction and magnetic attraction are developed in more detail. The electrical attraction occurs in different materials, while only the magnet attracts iron. Further, amber and jet were found to attract different kinds of material. This was a difficulty for the magical theories, since they relied on some common factor to provoke the sympathy. This same problem applied to the use of secondary qualities. A further distinction was that amber did not direct itself towards the poles. So the use of astrological rays as a source of power was also ruled out.

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