

# MAGNETISM OF THE GREEK ERA

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## Overview of Objectives and Historical Purpose

The traditional approach to history of science has been to emphasize what was wrong or incorrect in the ancient ideas. The result was an apparently positive approach, which beginning in the late renaissance around approximately 1600 A.D., reveals the birth of the scientific idea and its rapid development during the 17th century. The result is based on the conception that the Scientific Revolution is the most important event in the course of human progress. It is a value judgement typified by the following:

”...it outshines everything since the rise of Christianity and reduces the Renaissance and Reformation to the rank of mere episodes, mere internal displacements, within the system of medieval Christendom.”<sup>1</sup>

This approach is unsatisfactory, because it discusses ancient and medieval science in a derogatory manner, in order to contrast it with the correct modern viewpoint, with the purpose of emphasizing the superiority of the modern scientific method. This approach presents a discontinuous historical interpretation, where everything prior to 1600 is considered spurious knowledge. This approach is rejected here, where the objective is to present the modern as a continuous development of ideas. This interpretation presents the modern as a change in viewpoint, a difference in emphasis, with the fundamental issues remaining, they are merely framed in a different way. The questions are fundamentally the same; the answers are stated differently.

The history of magnetism in the pre-scientific age, prior to the development of modern science during the scientific revolution of the Renaissance, has not yet received the attention of historians sufficient to provide a detailed account of the progress of knowledge during this formative era of our civilization. In The Beginnings Of Modern Science, the author suggests that the

“...animist and vitalist obstacles impeded the study of magnetic phenomena right up to the Renaissance. It was only in 1600, when Gilbert’s *De magnete* appeared providentially as the herald of the new age, that magnetism not only took its rightful place among *physical* forces but became the basis of a new ‘magnetic philosophy.’”<sup>2</sup>

This prevailing view among the historians of science has apparently thwarted interest in the history of magnetism prior to 1600. A more recent book by Raymond J. Seeger, Galileo Galilei, his life and works echoes this prevalent misconception:

“The attraction of magnetite ore (an oxide of iron) was first mentioned by Thales of Miletus... Comparatively few additional facts were noted until 1600 when William Gilbert published his systematic study, marking the beginning of magnetism as a science; Gilbert accordingly has been called ‘the father of magnetism and electricity’.”

Here we see that the study of theories of magnetism has been ignored prior to Gilbert, and it will be surprising to discover their existence prior to 1600. The traditional interpretation faces a major problem; the publication in 1269 A.D. of the famous letter on the magnet by Peter Peregrinus. It forces upon us a discontinuous interpretation of magnetic history.

Behind the traditional historical approach, there is a hidden agenda, or prejudice. It conceives that only the modern is correct or true. It frames the historical record prior to 1600 in terms of incorrect belief, prejudiced by ignorance, superstition, and false religion. This is hardly difficult to accept when our modern culture still promotes the use of magnets to cure arthritis, and advocates the consumption of iron as a food additive. Both of these are ancient beliefs regarding magnets. One we believe to be false, the other true, yet both arise from ancient belief regarding the magnet. Our credulity is tasked. Are we really sure that magnets have no beneficial health effect?

Beyond this we must ask, did religion promote false science as we are told? Did the christian church cause the dark ages, was it hostile to the development of true knowledge, and promote the maintenance of superstition and erroneous knowledge? Did true knowledge only arise when the bondage of false religion was thrown off and the church's power over the human mind was destroyed? These are the ideas that underlie the traditional histories. We will consider them as we proceed.

Fundamentally, it is unfair to contrast the ancient with the modern. We really don't know much about the practice of ancient science that is directed to its methods. We have only fragmentary summaries of its conceptions. Consider if all modern scientific books were lost with the exception of a portion of popular literature. This consisting of popular science and cultural beliefs, it is clear that the historical record would be confused. The historical interpretation would certainly not reflect the truth.

The historical view presented here is framed as follows. The modern age, from which a continuous historical development can be constructed really begins in the middle ages around the 10th century. During this period there was a recovery of the literature of the ancient Greeks. This was added to the existing knowledge and traditions within the context of christian belief. The record prior to this time is discontinuous both in western europe and other cultures. We see this in the development of the compass, which appears in the 10 th century without any prior development. The history of science is similar. Prior to this we have few solid facts. But, many discontinuous fragments.

The early historical development appears discontinuous because there are no records that fill the gaps. Hence, landmark works appear without prior historical development. An example is the letter on the magnet by Peter Peregrinus which was written in 1269 AD. This letter records stunning developments of magnetical science. These appear without precedent or preparation. Did this knowledge spring suddenly from the genius of Peregrinus or was there prior knowledge for which the records have been lost?

Herein the approach will be to recover as much as can be expected from the meager records, and construct a continuous development of ideas. This development will be presented within the context of an historical interpretation. This interpretation is a theme or context of presentation. The theme is: The development of electricity and magnetism is the story of the development and conflict of two interpretive ideas or theories; the immaterialistic conception and the materialistic conception. These ideas develop and mature. They change form and context, but they remain basically the same at the foundations. We see them present today in the idea of the field and the quantum particle.

## **Introduction**

The Greek era (circa 650 to 100 B.C.) begins with the immaterial conception or spiritual conception of magnetism. This is explained in terms of magical sympathy or divine action. Thales represents a shift to a rational explanation of nature by a divine or immaterial force which pervades the material world. This immaterial force is hidden except for its actions resulting in movement and change, so it resembles a hidden soul. This is interpreted as the work of gods acting in accordance with a rational plan for nature which mankind can discover. This interpretation is followed by attempts to explain magnetic actions by natural processes involving the interaction of material substances having material properties akin to those known in the world. But this causes severe difficulties as pointed out by Plato in *Ion*. The materialist explanation fails even though the Roman poet Lucretius brings it to a high level of perfection.

The natural knowledge of the ancient Greeks and Romans was based on observation and rational explanation. This is distinguished from our modern conception of scientific knowledge by the addition of theory and experiment to these ingredients in the formulation of the scientific method. The concept of a scientific theory was unknown except in the most rudimentary form. This form consisted of a rational structure linking cause and effect, but the structure lacked the rigorous discipline of mathematics to prove conclusions and the test of experiment to assure validity.

Despite the inability to construct correct theories, the knowledge of the ancients is historically important because it was based on observation. Most of the common phenomena of electricity and magnetism revealed by the ordinary senses were known to the ancient civilizations. Two types of magnetic phenomena were clearly recognized and known before the earliest records were written by the Greeks around the sixth century before Christ. These were the attraction exerted upon iron by magnetized rocks or loadstones, and the ability to transfer this property to nonmagnetic iron through magnetic induction. The four types of electrical phenomena known and recognized by the Greeks and Romans were: lightning, St Elmo's fire and other luminous effects, the stunning shock of the torpedo ray -a species of electric fish, and the force of attraction exhibited by rubbed amber-the "amber effect". Modern science has succeeded in demonstrating that all these are caused by electromagnetism. Our goal here is to provide the background of natural knowledge prior to the beginning of the scientific age. We will try to interpret the rational explanations used to understand the observations by making them intelligible to reason.

Beginning with the two magnetic phenomena defined above, it is certain that both were discovered long before they appear in the written record. William Gilbert's account which appeared in On the Loadstone and Magnetic Bodies, rings true today:

“In former times when philosophy, still rude and uncultured, was involved in the murkiness of errors and ignorances, a few of the virtues and properties were, it is true, known and understood...when, by the genius and labors of many workers, certain things needful for man's use and welfare were brought to light and made known to others,... then did mankind begin to search the forests, the plains, the mountains,...the innermost bowels of earth, and to investigate all things. And by good luck at last the loadstone was found, as seems probable, by iron-smelters or by miners in veins of iron ore. On being treated by the metallurgists, it quickly exhibited that strong powerful attraction of iron--no latent nor obscure property, but one easily seen of all... then many ancient philosophers and physicians discoursed of it, and briefly(but briefly only) made it matter of record...”<sup>3</sup>

Certainly the marvelous loadstone was an object of curiosity and because of its magical properties commanded a high value in trade. The stones were used in magic shows and religious temples to illustrate magic and miracles. We believe that Thales of Miletus was the first Greek philosopher to discuss the loadstone. Aristotle records this fact, a second hand report, in his book On The Soul (De Anima, 405a19):

“Thales, too, to judge from what is recorded about him, seems to have held soul to be a motive force, since he said that the magnet has a soul in it because it moves the iron.”

### **Thales, Magic, Religion, and Animism**

Science history asserts that Thales of Miletus was the first scientist to study electricity and magnetism, thereby making him the first physicist. Historians of philosophy claim him as the founder of philosophy, while mathematics claims him as the father of mathematical proof. These views are not supported by the evidence which provides only the briefest hints supporting these opinions.

A long tradition of commentators and historians beginning in the Roman era and continuing through the middle ages has attributed the earliest record of magnetic attraction to Thales of Miletus (624-546 BC). In his 1899 book, A History Of Physics In Its Elementary Branches, Florian Cajori writes that Thales, one of the “seven wise men” of early Greece,

“...is credited with the knowledge that amber, when rubbed, will attract light bodies, and that a certain mineral, now called magnetite, or loadstone, possesses the power of attracting iron.”<sup>4</sup>

Other histories mistakenly assert that Thales “discovered” the attraction of amber. Modern scholarship has cast doubt on the accuracy of this conclusion. George Sarton dismisses the issue simply by asserting, “The tradition that would make him a founder of electricity is weaker and we prefer to omit it.”<sup>5</sup> This tradition derives from Diogenes Laertius who writes,

“Aristotle and Hippias say that Thales attributed souls also to lifeless things, forming his conjecture from the nature of the magnet, and of amber.”<sup>6</sup>

The testimony of Diogenes Laertius is important because it implies Thales was the first philosopher to attempt a rational interpretation of the behavior of magnets and amber. Thales produced no written documents. What we know is based on second hand knowledge, passed along as a verbal tradition until recorded by Aristotle in his writings. It is surprising that so much is attributed to Thales. An analysis by John Burnet, in his book Early Greek Philosophy<sup>7</sup> has reduced the information provided by Aristotle to three statements concerning Thales teachings:

- (1) The earth floats on the water.
- (2) Water is the material cause of all things.
- (3) All things are full of gods. The magnet is alive; for it has the power of moving iron.

These statements provide very little information upon which to make the assertion that Thales constructed a theory concerning the magnet and amber. What we do know is that the verbal tradition which Aristotle used to base his opinions of Thales, venerated him as the father of philosophy and mathematics. It is clear that Thales attempted to construct a cosmological system based on the idea of ultimate “stuff”, or substance of material cause, and asserted that water was this ultimate substance. However, the addition of the third statement concerning the existence of a soul in the magnet is difficult to understand within a system based on water as the ultimate substance.

Notice that in Aristotle, Thales is reported to have asserted that “the magnet has a soul in it because it moves the iron.” This is not the same as saying that “the magnet is alive” as derived from the report of Diogenes Lacertius. Thus we have ambiguity in the two pieces of evidence we have. Further, we have a second report from Aristotle On The Soul (De Anima, 411a7) that:

“Certain thinkers say that soul is intermingled in the whole universe, and that it is perhaps for that reason that Thales came to the opinion that all things are full of gods.”

This leads to the conclusion that Thales did not construct a theory or explanation concerning the attraction of the magnet or amber, but was using this phenomenon as an analogy to justify his cosmology. This was a combination of the idea of ultimate substance, i.e. water, with the idea of an “active soul” or “ultimate life force” in all things which animated the universe and all things in it. This idea is developed further in Plato’s theory of forms and ideas. Aristotle makes a critical distinction. For Aristotle, soul loses its universal character, by becoming an attribute only of living things.

What seems certain is that Thales was revered by contemporaries as the greatest of the wise, and that he introduced the notion of philosophical reasoning which attempted to make nature intelligible by generalizing about the first principles of cosmology. Thales used a method which reasoned from the observations, i.e. phenomena-things which appear, to explain the ultimate principles of nature. This is a primitive form of scientific or philosophical reasoning, but it can not be called natural philosophy. It is characterized by a method of deductive reasoning which

deduces proof of the hypothesis by demonstration of the phenomenon. This is illustrated by the quotation from Aristotle:

“Thales, too, to judge from what is recorded about him, seems to have held soul to be a motive force, since he said that the magnet has a soul in it because it moves the iron.”

Thales reasoning is analyzed as follows. I see that the magnet moves the iron, but the reason is hidden. I know that only living things can move themselves or move others. Living things have souls which are the cause of their motion. Therefore the universal principle of motion is that soul causes it. The proof is that the magnet moves the iron. Based on the observation of the magnet, Thales asserts the principle, soul is a motive force, and deduces the proof of this from, the magnet moves the iron therefore, it has a soul in it. Aristotle also tells us that Thales says, “...the earth rests upon water”:

“It (the earth) was supposed to stay still because it floated like wood and other similar substances, which are so constituted as to rest upon water but not upon air.”

Here again is the method of reasoning that proves the hypothesis on the basis of the phenomenon. Thales reasons as follows. I see that wood floats on water, therefore because the earth must be supported, the earth floats on water, and the proof of it is that wood floats on water. Thales reasons in a circle, the result or observation implies the cause, and this is inverted to prove the cause from the result. This is called a teleology, or teleological reasoning. Simply put, it is reasoning in a circle. This was a characteristic method of thought in an era closer to religion and magic than disciplined philosophy.

To the modern mind, this is obviously fallacious reasoning, but it is not until Aristotle that rules for reasoning are clearly established. This became necessary in order to correct the fallacious reasoning widely employed by the sophists as well as the pre-socratics. The main difficulty with the method employed by Thales and the pre-socratics which followed his method was the inability to separate this form of reasoning from magic and religion. Further it led naturally into animism and hylozoistic philosophy.

The basic idea of magic is a belief in a hidden mysterious power, supernatural, and immaterial animating all things. Magic consists of methods to control the hidden forces or causes which animate the world. It is a human art practiced through the agency of ritual by the exercise of personal will over the forces of nature, bending them to man's will safeguarding his welfare and shaping his destiny. How does this view of nature arise? The magical ritual enters at the point where man's knowledge and foresight begin to fail, where luck, chance, and ignorance of the hidden causes impair the reliance on rational action. Magic, through a firm belief in his own power, provides man with an assurance of control over nature. James Frazier emphasizes this point: “Magic is a spurious system of natural law as well as a fallacious guide of conduct; it is false science as well as abortive art.” Thus magic arises from a fallacious attempt to understand the hidden forces of nature. This has influenced Thales view of the world, because he tries to explain the motion of iron towards a magnet by saying that the magnet has a soul.

This is a complicated idea for the modern mind. It invokes the magical law of sympathy, which means there is a hidden or occult relationship connecting things which have sympathy. It is a causal law of relation such that one thing exercises control over the other, with the effect that whatever one does or suffers the other is inevitably bound to do. Sympathy is a hidden bond between a man and his image, as in voodoo dolls, between a man and his hair-trimmings, or between a man and his name so that a man can be cursed through a ritual by uttering his name.

It is easy to see how the attraction of a magnet for iron resembles the relation of magical sympathy. The magnet exercises an attractive force on the iron, drawing it towards itself. This fact is emphasized in the names given to the magnet by the ancient cultures which refer to it as loving, a term which evokes the magical idea of sympathy. In Sanskrit the magnet is called “loving toward iron”, in Spanish “loving stone”, the Chinese and Hungarians called it “love stone”. In this context, love implies a sympathy, since love is the strongest form of human relation arising from sympathy. Now if it is agreed that love is a relation of one soul for another, Thales’ assertion becomes intelligible in terms of a magnetic sympathy for iron. A relation which invokes the magical law of sympathy so that the magnet draws iron towards it or induces iron to follow its movements. Here is the connection with the modern concept of induction, an idea which originates in sympathy.<sup>8</sup>

Electricity, the attractive effect of rubbed amber, has also been associated with magical sympathy.

“The name of the precious stone inserted in the ring of Gyges has not been handed down to us, but it is probable that it was the topaz, whose wonders Philostratus recounts in the life of Apollonius. An attribute of the sun and of fire, the ancients called it the *gold magnet*, as it was credited with the power of attracting that metal, indicating its veins, and discovering treasures. Heliodorus, in his story of Theagenes and Caricles, says that the topaz saves from fire all those who wear it, and that Caricles was preserved by a topaz from the fiery vengeance of Arsaces, Queen of Ethiopia.”

In these legends, the magical effect of electricity has been extended, through a sympathy derived from its yellow color, to the power to discover gold, and the protection from fire. Similarly, the magnet is said to “restore husbands to wives” because of its sympathy with love.

Histories of magic, based on the Hermetic tradition, suggest that knowledge of the magnet originated with the Magi, plural of magh, or magus, who were the first to discover its attraction for iron. Consequently, the wonderful stones were named in their honor. The word magnet deriving from the Sanskrit root word, mahaji, meaning the great or wise. Their temples were widespread, some were named after Hercules, hence the name Herculean or Heraclean stone for the magnet. Although unreliable for good historical work, these facts are probably not completely apocryphal. Despite the fact that there are no written records to demonstrate that magnets or loadstones were known to the Babalonian and Egyptian temple priests, there is some evidence to suggest a connection. The Egyptians believed the sky to be made of iron or steel, hence the name for iron, metal of heaven. This may have been the motivation for the attempt described by Pliny to suspend an iron statue in an Egyptian temple:

“The architect Timochares had begun to use loadstone in the construction of the vaulting of the Temple of Arsinoe at Alexandria, so that the iron statue it housed might appear to be suspended in mid-air, but the project was halted by his death and the death of King Ptolemy who had commissioned this work.”<sup>9</sup>

An old fashioned English translation of Pliny tells us the same thing, but in a more entertaining fashion.

“Dinocrates (sic) began to make the arched roof of the temple of Arsinoe all of magnet, or this loadstone, to the end that within that temple the statue of the said princesse made of iron, might seeme to hang in the air by nothing”<sup>8</sup>

Another source contradicts Pliny, claiming that the temple was actually completed, but it is known that the project could not have actually been completed, because modern physics indicates that the suspension of the statue is mechanically unstable.

“Timocrates suspended the statue in mid-air...under the ceiling-vault crowned with loadstones, a bluish magnet draws, by means of an iron hair, the young woman it holds in its embrace.”<sup>8</sup>

Harkening back to Thales idea of a soul in the magnet, in Egypt and Samotrache magnetic stones were worshipped because they contained souls which had fallen from heaven. These stones might have been meteorites, some of which are highly metallic.

When Thales says that a magnet has a soul in it, he invests it with an immaterial principle of action. Modern science calls this magnetic induction. The medium through which the action is effected is called the magnetic field. It is an immaterial or imponderable substance, which acts through a hidden or occult force. Unlike science, religion relies on the abstract concept of a god, a divine will, to explain an immaterial or hidden cause of action. The important question is, why does Thales say, the magnet has a soul? If Thales is correctly believed to be the father of natural philosophy, the first proto-scientist, then why does he make religious assertions: All things have gods in them, the magnet has a soul?

The answer may be related to the question, why is Thales mentioned by Aristotle in connection with the magnet, in a treatise On the Soul. This is remarkable because Aristotle never mentions the magnet again in any of his writings. The magnet appears at the very beginning of Greek scientific discussion, and then seems to languish. The answer is not because Thales is presenting a theory of the magnet, it is because this is one of the two most memorable ideas associated with Thales.

We must consider that Thales is probably not the founder of Greek science, but that he represents a paradigm shift. Thales was not himself responsible alone,

“Thales is traditionally the first to have revealed the investigation of nature to the Greeks; he had many predecessors, as also Theophrastus thinks, but so far surpassed them as

to blot out all who came before him. He is said to have left nothing in the form of writings...”.

Thales represents a change in scientific fashion, a shift in the intellectual culture of his era. This shift is epitomized by the statement found in Aristotle's On the Soul. The paradigm shift was a change from the religious mythology, where the Gods or the divine was conceived outside of nature controlling it through the action of divine sympathy, to the conception that the divine was within nature itself. Hence “all things are full of gods”. Thales stands in history as a representative of a new idea, the idea that the divine is to be found within nature, because nature works according to the divine in it. The primary example of this viewpoint is the magnet which illustrates the point. The magnet moves the iron, because of the divine within it.

Thales is rightly considered the founder of science because he is the first to introduce a new philosophical idea; that nature acts according to the divine within it. Translated into the modern conception, Thales conceived that the universe consisted of two principles matter and energy. For Thales, water was the principle of matter because it was the source of all things. The active principle of energy and forces was recognized as well, since inanimate objects such as the magnesian stone can impart motion to iron.

Did Thales discover magnetism? The answer is clearly no. He used a well known phenomena, magnetic attraction, to illustrate his idea that nature possessed an active principle or soul. This phenomena was well known before Thales used it to express his new conception of nature.

### **The Materialistic Theory Of Electric and Magnetic Attraction**

The new paradigm of nature, that it works by the divine in it, was the stimulating idea for the development of Greek science. But, the simplistic idea that the divine acted directly to cause the motion of the iron, was not sufficient. The divine acted within and through the material world. This required an inquiry into the cause; conceived as the divine acting according to its nature. Hence a growing emphasis on the material interpretation or explanation of nature.

The second ingredient of Greek science that develops is the use of deduction as a form of proof. This is the really important innovation that makes science possible. The idea is that nature conforms to reason, therefore its workings can be discovered by observation and the application of reason. This idea undergoes a crisis due to the criticisms of Parmendies, who attacks the fundamental assumption that truth can be obtained by observation, because the senses are fallible. This leads to a theory of sense perception developed by Empedocles.

Emdedocles is exceptional because of another innovation which he introduced; proof by demonstration experiment. The proof involved showing that air is corporeal by using a water clock. This led to a dramatic shift in scientific fashion, by inaugurating the materialistic theories of occult action. By proving that air, which is invisible, and insensible is a corporeal material body. Empedocles showed that it was possible to explain the unseen divine actions of nature by corporeal agents.

The second known attempt to construct a magnetic theory was by Empedocles of Akragas (or Agrigentum) (491-435B.C.). We know this through the second hand account of Alexander of Aphrodisias who paraphrases Empedocles theory.

“Why the Heracleian stone attracts iron. Empedocles says that the iron is borne towards the stone by the effluvia emanating from both and because the pores of the stone are fitted to receive the effluvium of the iron. The effluvium of the stone then expels the air from the pores of the iron. Once the air is expelled, the iron itself is carried along by the abundant flow of the effluvium. Again, when the effluvium of the iron moves towards the pores of the stone, which are fitted to receive it, the iron begins to move with it.”<sup>10</sup>

The theory establishes the materialistic theory of attraction based on a mechanical explanation. This contrasts with the Thalean theory which attributes the attraction to a nonmaterialistic, hidden, or occult cause. These two views constitute the two main viewpoints used to construct theories of electricity and magnetism throughout the prescientific era and dominated the thinking of the early scientific age up to the beginning of the 18th century. All the theories constructed since the days of the ancients can be classified as either materialistic, based on the action of effluvia in the form of tiny insensible particles, or as a nonmaterial hidden force of attraction that acts at a distance across the intervening space.

The materialistic viewpoint, which is the dominant modern opinion, contrasts with the immaterialism of Thales. It is a philosophy which attempts to explain phenomena in terms of material action. Its roots are often incorrectly traced to Democritus who is thought to be the founder of a crude atomic theory. The basic idea underlying this approach is the hypothesis that the unseen action of attraction exhibited by the magnet and amber is caused by tiny subtle particles which are emanated or exhaled by the magnet or rubbed amber. These were supposed to be unobservable by normal means but were revealed by their actions. This idea of the existence of unseen and unsensible matter, so tiny and subtle that it was able to penetrate the pores of material substances is a recurring theme. It appears again and again, wearing different appearances. It rises to prominence in the late middle ages and renaissance, forms the basis of Descartes physical system, then recedes with the rise of Newtonian action at a distance, appears again in the system of Abbe Nollet, fades with the rise of modern field theory, and finally rises again in the modern theory of quantum electrodynamics.

The common element in these theories being the existence of the invisible subtle and tiny particles which act across the intervening space to effect the attractive or repulsive action. This view contrasts with the contrary immaterial cause which invokes an unknown active power or virtue whose action pervades the surrounding space to effect the attractive or repulsive actions. Although both causes are hidden or occult, we refer to the latter as the occult cause, because there is no material cause invoked to explain the phenomena.

In many ways the materialistic theories are more interesting because of the ingenuity they reveal regarding their authors. The difficulties are severe. There are two of them. First to define the nature of the emanations and the second to explain how these emanations act to exert the attractive force. An example is the ability to act through intervening material substances. This required that the material cause be both unseen and able to penetrate intervening matter. Finally,

since there was no scientific basis for mechanical action, the explanation had the major difficulty in explaining how the action of the emanating material resulted in an attractive action. This last difficulty eventually resulted in the effluvia concept. The effluvia were conceived as entangling the attracted object and drawing it towards itself by embracing it. Theories using the materialistic concept usually invoked a subtle emanation or effluvia, but vary widely regarding the means by which the attraction is effected.

It is beyond the scope of this book to discuss in detail the theories of the ancient philosophers. They invariably invoked the explanation of electricity or magnetism as an application of their larger world system to a specific case. In the case of Empedocles, his subtle particles form the essential feature of his theory of sense perception. His idea being that the emanation of the subtle particles by all matter resulted in sense perception when they entered the pores of the sensing being. One example being his explanation that the eye sensed light to produce vision by the reception of these subtle emanations of the object observed. This sounds remarkably like the modern concept of the photon used to explain sight.

To explain the attraction to the magnet Empedocles invoked the following:

“effluences from the magnet fit the pores of the iron and by entering them drive out the air which they contain. This increases the flow of effluences from the iron so powerfully that as they press into the pores of the magnet the iron itself is drawn after them.”<sup>10</sup>

So the theory of the magnet evolved as an adjunct to or subsidiary theory from Empedocles theory of sense perception. The theory was attractive because it explained why only iron was effected by the emanations. The pores were fitted only to the iron, and not other materials, hence it only acted on the iron. A criticism of this theory was that it failed to really explain the attraction because there is no reason to suppose the force would be attractive as opposed to a repulsive force. The main idea is that the vacuum created in the iron pulls the magnet towards it. So the explanation failed, since the repulsive force was not known at that time.

A different viewpoint was taken by Diogenes of Apollonia. He sought to explain the action on the analogy of breathing. Inanimate substances were thought to inspire and expire a kind of dampness or moisture. Hence the expiration or expulsion was analogous to sweating. The magnetic attraction was interpreted as caused by the attracted iron absorbing more of the expired emanations than it ejected, hence the iron was drawn towards the magnet. The iron draws in the sweat. This also explained why only iron was attracted, other substances did not exhibit the same ability to absorb the moist emanations as iron. They did not draw in the sweat as effectively as iron. Because the iron sucks the moisture in “all at once” the action is sufficiently powerful to drag the iron into the magnet.<sup>10</sup>

The contribution of Democritus was to interpret the emanations as caused by his atomic particles or atoms. These are not to be confused with the modern conception. According to Alexander of Aphrodisias who is our primary source on this subject:

“Democritus also says that there are effluences and that like bodies are attracted to like, but adds that all are attracted to a void. Having made these hypotheses, he supposes that

the loadstone and iron consist of similar atoms, but those of stone are smaller and it is of some rarer texture than the iron and contains more void. For this reason, its atoms being more mobile are attracted more quickly to the iron (for they are moving to their similars), and entering the pores of the iron disturb the atoms in it as they pass between owing to their small size. The atoms of the iron, thus disturbed, stream outside towards the stone because of their similarity and because it has more void. The iron [as a whole] follows them in their wholesale expulsion and movement and is itself drawn towards the stone. the reason why the stone does not move any more towards the iron is that the iron does not contain so much void.”<sup>10</sup>

The emanation theory was also embraced by the Greek philosopher Epicurus (342-270 B.C.) who writes the following explanation for the action of the magnet:

“The lodestone or magnet attracts iron because the particles which are continually flowing from it, as from all bodies, have such a peculiar fitness in form to those which flow from iron that, upon collision, they easily unite.”<sup>11</sup>

## **PLATO S IMMATERIALISM**

The first complete first hand historical record regarding magnetic induction appears in one of Plato’s dialogs, Ion, written around the year 350 B.C. The dialogue occurs between the great Socrates and Ion of Ephesus, a reciter of poems and songs. In a passage where Socrates is explaining his reason why Ion is a successful reciter, Socrates says:

“Really, as I said just now, this is no art in you to speak well about Homer; no, some divine power is moving you, such as there is in that stone which Euripides called the Magnesian, but most people call it the Heracleian stone. This magnet attracts iron rings, and not only that, but puts the same power into the iron rings, so that they can do the same as the stone does; they attract other rings, so that sometimes there is a whole long string of these rings hanging together, and all depend for their power on that one stone. So the Muse not only inspires people herself, but through these inspired ones others are inspired and dangle in a string.”<sup>12</sup>

This passage is remarkable because it uses magnetic induction to clarify by analogy Socrates explanation of the inspiration of the Muse. For the analogy to be understandable, Plato needed to choose a well known phenomenon, otherwise the analogy is less intelligible than the thing he is explicating. This demonstrates that observational knowledge of magnetic induction was common at the time, i.e. 350 B.C.

There are two ways to interpret this passage from Ion. We can take it at face value, or we can read into it an interpretation that returns to the immaterialistic viewpoint of Thales. Plato’s purpose is to refute the idea that the art of the reciter is solely responsible for the spellbinding rapture of the audience. It is not the art of recitation but the divine within the poetry and the reciter which inspires these raptures. Plato concludes that a divine dispensation for the poet allows him to inspire by the divine art of poetry the souls of the listeners, just as the soul of the loadstone incites or activates the souls of the iron rings causing them to form into a chain. Hence, the cause is the divine in the poetry which is imparted to the audience. We see that this viewpoint

is also a refutation of materialism. Plato cites a physical phenomena which demonstrates by an observation of nature that the divine must exist. It is an extension of the example cited by Thales. Plato demonstrates that an explanation of magnetic attraction is not a sufficient proof. It is also necessary to explain the propagation of this attraction to iron rings which did not possess this property until placed in contact with the magnet. Hence, it is not just the magnet alone which possesses the attractive power, but the other rings can also acquire this power from the inspiration of the magnet. This inspiration can only be explained by the existence of a divine or immaterial force in nature.

In his last dialog, Timaeus, Plato refers to “the wonderful attracting power of amber and the Heracleian stone”. This dialog is significant because it represents the earliest preserved complete primary source record of a cosmology in the scientific sense; a theory of the origin of the universe and everything in it, which is derived from first principles and not based on myth. In one stunning paragraph, Plato links lightning, with electricity and magnetism and presents a theory to explain them. In the course of explication of his principle of circular thrust Plato has Timaeus cite examples where the principle applies:

“Other examples are any stream of flowing water, the fall of thunderbolts, and the puzzling attraction of amber and loadstone.”

Here there is an explicit linking of the attractive phenomena of electricity and magnetism. However, the connection with lightning is unclear. While tantalizing to think that Plato recognized that lightning was electricity, there is no reason to believe that Plato is actually saying that lightning is caused by electricity. He is asserting that the principle of circular thrust applies to these examples.

Plato follows the preceding with an explanation as follows:

“In fact there is no attraction. Proper investigation shows that there is no void and that circular thrust operates in all these instances; 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 a sense, the principle of circular thrust is like the modern conception of action and reaction. Since there is no vacuum or void, every action engenders a counter action. The problem is that Plato, while conceiving this applies the idea incorrectly. Hence in explaining respiration, which is his primary purpose in introducing circular thrust, he correctly concludes that exhaling induces inspiration, but he gets it wrong because he infers that the air is forced into the lungs through the pores in the body. It is a curious conclusion, which makes the argument unconvincing. The idea however, could be sound if applied properly as in the modern approach. Here we see that Plato infers that attraction is mutual, but he is not clear about how this actually occurs.<sup>13</sup>

The two dialogues of Plato which discuss magnetism give us two different viewpoints. The first dialog gives an immaterialist conception that presents difficulties for the materialist model. In the Timaeus, a materialistic explanation is attempted. It is not very satisfactory and is incomplete.

The main difficulty is the explanation of the hidden and immaterial forces of magnetism which demand an explanation of both magnetic attraction and magnetic induction.

### **Aristotle's Apparent Silence On Magnetism**

This section address Aristotle's viewpoint and his silence on a theory of magnetism. The interpretation given here is that although Aristotle does not address magnetism directly, he does give us an indirect way to infer his viewpoint through an analysis of his discussion presented in *On The Soul*, Book I Chapter 3 and in *On Generation and Corruption* Book I, Chapters 7 to 10. The conclusion is clear, after an analysis of the immaterialist and materialist viewpoints, he finds that both of them contain serious logical flaws. Given this problem, he does not attempt to give his own interpretation of magnetism. His main objective is to redefine the concept of soul, and this project demands his full attention.

The essence of Greek rational science is its characteristic reasoning from observation of nature applied in logical manner. The early Greeks prior to Socrates reasoned in the manner typical of Thales. Observational experience was used to infer the principles of nature. But the application of logical method required that conclusions be deduced logically from principles just as effects flowed from causes. But what were the first principles from which the interpretation of nature was derived? This question was debated and different opinions were advanced. So far, this history has identified two main concepts, the soul as an immaterial cause and atoms as a material cause, which were advanced as first principles for the explanation of magnetism. But both of these theories should be understood as an attempt to understand how the soul within the magnet imparts a moving force to the iron it attracts.

Socrates invented the method of dialectic reasoning which was developed by Plato into a highly effective method of reasoning. Aristotle made a very decisive step when he invented systematic rules of logical reasoning and developed a formal system of scientific reasoning. Aristotle should be correctly described as the founder of scientific thought because he integrated two aspects of Greek philosophic method into a new system, which can properly be called scientific, because it brought together the two main ideas into a system for the first time. Aristotle took the traditional method of reasoning from the observation and experience of nature and combined it with a system of logical reasoning about nature and invented natural philosophy. This is a precursor to what we call science or modern scientific method. The main difference is really two-fold. The idea of inductive reasoning from experience is modified by the concept of experimental proof and the deductive method is modified by replacing the Aristotelean logical method with the certitude of mathematical reasoning and proof by formal reasoning conducted mathematically.

In *On The Soul*, Aristotle applies his method to both the immaterialist and materialist theories of the soul. He analyses both viewpoints and finds logical flaws in both of them. Prior to Aristotle's analysis of soul, the Greeks viewed the soul as a self moving ultimate cause of motion. Soul for the Greeks prior to Aristotle is best described not as the christian soul we know, but as a living energy and active agency that animated the world. In this sense, soul is more like the modern idea of energy which provides the vital active source of life and movement within matter that is responsible for motion and change. So the Greek idea of soul is more like our

modern idea of energy or vitality than our modern concept of soul. It is due to Aristotle that this change in emphasis occurred.

The idea of soul as a vital energy animating the world is clearly expressed in Thales theory of magnetism. He uses the magnet to illustrate the idea. This is such a memorable and striking concept that Aristotle mentions it twice in his treatise on the soul. But Aristotle rejects Thales idea that “soul is a motive force” because “it is false that the essence of soul is correctly described by those who say that it is what moves ( or is capable of moving) itself, but it is an impossibility that movement should be even an attribute of it.” Aristotle in his analysis begins with the idea that soul is a source of motion and rejects it.

He gives a detailed analysis which is difficult to follow and understand. The essence of it is the analysis of the question: How can the soul in moving itself cause the body within which it is contained to move as well? Aristotle considers this problem and concludes that both the immaterialist theory and the atomistic theory are flawed and fail to give an inadequate explanation. This argument is most effective against the theories of Empedocles, Diogenes and Democritus who assert that movement is caused by “the subtlest and most nearly incorporeal of all kinds of body”. Aristotle asks how can these subtle atoms of soul be joined to the material of the body so as to cause its movement? He tells us that since no answer is given by the proponents of this theory, the theory must be rejected. The viewpoint of Thales is rejected as follows:

“Certain thinkers say that soul is intermingled in the whole universe, and it is perhaps for that reason that Thales came to the opinion that all things are full of gods. This presents some difficulties: Why does the soul when it resides in air or fire not form an animal, while it does so when it resides in mixtures of the elements, and that although it is held to be of the higher quality when contained in the former?...it is beyond paradox to say that fire or air is an animal, and it is absurd to refuse the name of an animal to what has soul in it.”

Aristotle’s conclusion is that a redefinition of soul is needed. He says regarding the views of previous philosophers: “...let us now dismiss them and make as it were a completely fresh start, endeavoring to give a precise answer to the question, What is soul?”

The new approach for the definition of soul which Aristotle gives, leaves the idea of the magnet as containing a self moving soul behind. It is no longer a relevant question for philosophy, but remains a question for physics which is unanswered. But Aristotle does not have an answer to explain the attraction of the magnet for iron. The expulsion of soul from the inanimate world creates more questions than answers. A new approach to the theory of motion is required. But, the theory of motion advanced by Aristotle is not capable of encompassing magnetism. This is because his theory of motion requires a physical contact between the mover and the moved. When we examine Aristotle’s treatise On Generation and Corruption this problem is analyzed in more detail.

In On Generation And Corruption, Aristotle presents a refutation of the atomic theory of the action of one body upon another. This theory was crucial of the theory of sense perception invented by Empedocles and elaborated by the later atomists. In book I, chapter 8, Aristotle says:

”Some philosophers think that the “last” agent -the agent in the strictest sense- enters in through certain pores, and so the patient suffers action...Such was the theory which some philosophers (including Empedocles) advanced in regard to the structure of certain bodies. They do not restrict it to the bodies which act and suffer action: but ‘combination’ too, they say, takes place only between bodies whose pores are in a ‘reciprocal symmetry’ .”

When reading this section carefully, it is apparent that Aristotle is addressing a general theory of combination, which today we call chemical change. But the same general principles apply to Empedocles theory of magnetism, which used the same basic ideas to explain the attraction of a magnet for iron. Here the combination between bodies refers to attractive forces between them. This doesn’t help us understand how the motive force of attraction is generated, but does make clear the need for an idea of reciprocal action, which today we find expressed in physics as Newton’s third law of motion. The modern theory of matter makes this attractive force a necessary condition in order for the atoms to combine into a bulk mass that is coherent. Aristotle uses the absence of this principle in the atomic theory to show why it is absurd. Essentially his argument is that if solid bodies contain pores continuously throughout them they must either fall apart or contain nothing but the void.

Aristotle’s conclusion at the end of Chapter 8 is a damaging refutation of the magnetic theory of Empedocles and the atomists:

“As a general criticism, we must urge that to postulate pores is superfluous. For if the agent produces no effect by touching the patient, neither will it produce any by passing through its pores. On the other hand, if it acts by contact, then- even without pores-some things will ‘suffer action’ and others will ‘act’, provided they are by nature adopted for reciprocal action and passion. Our arguments have shown that it is either false or futile to advocate pores in the sense in which some thinkers conceive them. But since bodies are divisible through and through, the postulate of pores is ridiculous: for, qua divisible, a body can fall into separate parts”.

Aristotle defined motion as a general principle of physical movement and change or alteration. Hence growth of plants and animals could be analyzed as a motion in terms of alteration in size. This means that the theory is intended to be as general as possible, so that it applies to all forms of motion. In the case of magnetism we have a particular case of local motion or a change in place induced in the iron when a magnet is placed close to it. We require an explanation as to the cause of this motion. But Aristotle nowhere addresses this specific case. The goal here is to infer what the explanation ought to be based on the principles enunciated by Aristotle in this treatise.

Aristotle has been described as impeding scientific progress for more than two thousand years. This view is false for a number of reasons. In the first place, Aristotelian thought was not immediately successful in its own time. It did not immediately sweep the ancient world and dominate its thought. In fact Aristotelian method nearly disappeared entirely. Aristotle’s Macedonian citizenship and his association with the hated Macedonian empire of Alexander resulted in personal animosity and vilification against him remaining in Athens, and he removed to the island of Chalcis. Aristotle’s friend and successor Theophrastus inherited his lecture notes, books, and papers and remained in Athens carrying on the work of Aristotle’s school the

Lyceum. However, when Theophrastus died he did not bequeath the body of Aristotle's written works to his successor or to the school itself but to his nephew, Neleus of Scepsis.

This step has never been explained. How could the school carry forward teaching Aristotle's methods without the guidance of his lecture notes and papers? A suggested explanation may be the continued enmity towards the school as a result of its association with Aristotle and his Macedonian connections. Theophrastus may have decided that a separation of the school from any formal connection with Aristotle would improve its financial viability. The school was apparently never really successful or highly influential and had declined so much that it was defunct or nearly so after only 100 years.

After Nelus of Scepsis died, some of Aristotle's papers were acquired by the great library of Alexandria. Others were acquired by Apellion of Teos. Then an historical event occurred that had a profound impact. In 86B.C. the Roman general Sulla captured and sacked Athens. Sulla acquired Apellion of Teos collection and carried it to Rome. Many of Aristotle's books were transferred into the hands of Roman intellectuals perhaps others discussing a theory of magnetism were lost. Others were dispersed far and wide. But the Romans did not read Greek, and Greek learning which had once been centered in Athens was dispersed and destroyed. It was many years before Aristotelian thought made a recovery at the hands of a small group of adherents.

A more decisive reason that Aristotelian thought did not dominate philosophical discourse was that it did not resonate within the ancient world. Other philosophical systems competed and were more dominant. The Romans, who were militarily, politically and economically dominant, preferred the Stoic and Epicurean systems. Furthermore, the Romans disdained having to learn and read Greek. Finally and most important, the main problem with Aristotle and his interpretation is that his philosophical system was not understood and commentaries tended to confuse and obscure the method and its conclusions. Primarily, Aristotle presents a method of reasoning and examples for its application in terms of the kinds of problems which he addresses. His followers and his opponents clearly did not really understand the method and its application. They tended to interpret his books as received knowledge rather than tentative knowledge demonstrated by the new method. Hence the authority of Aristotle was in its method not its conclusions. But the method had been lost before Sulla's sack of Athens when the school itself had closed. Hence it appears that the commentators who revived Aristotle had to reinvent the method by putting the disparate collection of lecture notes into some kind of logical order. This effort was successful in one sense, but in another it seems that his later disciples were unable to fully resurrect the spirit of his method because they did not fully understand it.

## **POST-ARISTOTELIAN PHILOSOPHY**

The period following the dissolution of the Macedonian empire of Alexander can in one sense be described as a period of decline, but another view of it is that it was a period in which the seeds sown during the golden age of Socrates, Plato and Aristotle took hold and began to produce ideas that diverged from those of the founders of philosophy. At least five main philosophical schools emerged during the period from about 300BC to the end of the Greek era: the Academy or Platonic school, the Aristotelian or peripatetic school also known as the Lyceum, the Epicurean

school, the Stoic school, and the Skeptic school. These schools resulted in a fragmentation of philosophy, but they also contributed new ideas that we will encounter in the history of magnetism.

From the point of view of our history of magnetism, the most important of these schools was the Epicurean. One reason for the decline of the Aristotelian school of thought may be the tremendous success of the school founded by Epicurus. It was very successful and Epicurus was loved and revered. The man was a great philosopher and educator and he developed a theory of magnetism which far surpassed any before it in its comprehensive detail. Epicurus (342-270 B.C.), who founded his school in Athens in 306 B.C., developed his theory of magnetism following the style of the materialist tradition of Empedocles, Diogenes, and Democritus. He took as his principles atoms and the void. Although his detailed theory of magnetism described in his own words has been lost, we possess a very accurate idea of it from the work of Lucretius. This will be discussed in the following chapter.

The problem presented to the atomists was to explain how the soul of the magnet, its source of action or movement, could be explained within the idea that the soul is corporeal composed of atoms. The main difficulty being the problem to explain how the soul of the magnetic force coexisted with the matter of the magnet, while at the same time was capable of acting as if it was an incorporeal force. In the middle ages, this action of the magnet was described as occult or hidden. The theory required that the atoms responsible for the cause of magnetic movement be so subtle that they were essentially insensible. But, this demanded an explanation as to how these insensible atoms, imperceptible to the senses, could act upon the iron to impart motion to it. There was also the further problem to explain why the iron remained attached to the magnet, and further how this attraction was communicated from the magnet to the iron and then making the iron, which it touched, into a magnet as well.

These problems were eventually solved by the Epicurean school and found a complete expression in Lucretius. What we know of Epicurus indicates that he thought that: "The lodestone or magnet attracts iron because the particles which are continually flowing from it, as from all bodies, have such a peculiar fitness in form to those which flow from iron that, upon collision, they easily unite."

This explained why the magnet attracted or acted only upon the iron, but not anything else.

The Stoic school did not make any specific contributions to magnetic theory, but they did contribute a very important idea, astral determinism, that was to become significant much later. They were also responsible for developing the idea that the universe is connected by an all pervading force. This is a paraphrase of the basic idea, but is easy to see how it developed into the astrological idea that from the stars emanated a force that controlled the lives of men in the world a force which controlled the tides as well as the fortunes of men. The irony of the stoic school is that its philosophy returns us to the basic idea that was the foundation of Greek natural philosophy. This is the conception that nature is activated by the divine force that interpenetrates all things. It is the immaterialism of Thales conception that all of nature contains the divine spirit. This was an idea that resonated not only in the pagan world but with the christians and christian theology.

## SUMMARY AND CONCLUSION

We began by defining the Greek era as the period from 650 B.C. to 100B.C. It begins in the birth of the Greek scientific spirit with the Milesian philosophers who were in contact with the ideas and knowledge of the orient. It ends with the subjugation of the Greeks under the expansion of the Roman republic. The peak flowering of the scientific idea occurs during the reign of Alexander the Great. His patronage for his tutor Aristotle resulted in the great encyclopedic collection of scientific studies undertaken by Alexander's order. With the dissolution of Alexander's empire, the scientific spirit declines in Greek philosophy. The period from roughly 300B.C. to 100B.C. is a period during which Roman power expands. With the defeat of Carthage, Greek fortunes declined as well, for the Greek states in Sicily and the Macedonian kingdom were allied with Carthage. By the end of the Greek era, all of the vast empire of Alexander had been either absorbed by the Roman republic or reduced to the status of a subordinate to Rome.

The subjugation of the Greeks was both a political and cultural blow to the growth of science. The Romans were primarily interested in wealth and business. Greek learning and culture was an adornment for the rich roman patricians who sent their sons to be educated in the Greek schools, but there was no love of philosophy in the Romans. They were motivated by money. During this period we see the rise of the stoic philosophy which was more in tune with the chaotic world of war and distress than the world of Alexander the Great.

To conclude this discussion, consider the following quotation concerning the state of scientific learning in antiquity from a respected treatise on the history of science by Renee Taton:

”The greatest temptation was to explain magnetic phenomena by animalistic and vitalistic theories. While even the ancients had little difficulty in fitting other physical phenomena into some sort of coherent framework, magnetism was so shrouded in mystery that it was left outside their theories of nature.”<sup>2</sup>

The author violently disagrees with this conclusion and hopes that the reader agrees. The purpose of this chapter was to demonstrate that this opinion is false and harmful to the correct understanding of electricity and magnetism in antiquity. It is simply untrue that magnetism was shrouded in mystery. This exaggerates the situation. True, the facts were confusing and unclear, but there were specific facts well known and understood that defined the requirements of a successful explanation.

We have seen that the predominant theories were materialistic. The immaterialists never offered a theory in the scientific sense. There was a long and concerted effort to establish materialistic theories based on the theory of emanations and effluvia. These theories were never able to overcome the difficulties posed by the phenomena. Hence the continuance of the “animalistic and vitalistic” theories throughout the ages was not due to the reason proposed by Taton. The reason was that they provided better explanations in light of the known evidence. How can you disagree with this view when you consider the description in Plato's *Ion*? The ancients were simply unable to provide a materialistic explanation for the phenomena of the hanging rings.

Why was the force of attraction transmitted from the magnet to the rings? The power of sympathy was not a satisfactory explanation from a materialistic viewpoint, but materialists could not offer an inadequate material cause. Hence we should not be surprised that the immaterial and occult causes continued to attract attention and were widely accepted. This situation remained until the advent of field theory, which postulated an immaterial concept, the field, to explain the transmission of the electric and magnetic forces.

**Next Chapter**

**Exit**

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