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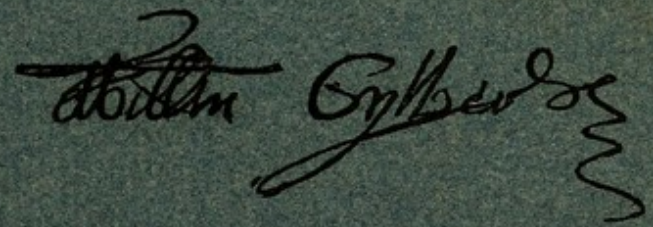

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WILLIAM GILBERT AND TERRESTRIAL MAGNETISM IN THE TIME OF QUEEN ELIZABETH.

ILLIAM GILBERT, the father of electrical ſcience, was born in Colcheſter in 1540. Educated at St. John's College, Cambridge, where he took his degree as Doctor of Medicine in 1569, he ſettled, after four years of foreign travel, in London in 1573, and was admitted to the Royal College of Phyſicians, of which he became Cenſor, Treaſurer, and, in 1599, Preſident. He was in February, 1601, appointed perſonal Phyſician to the Queen, whom he attended

in her laſt illneſs. He came of a well-known Eaſt Anglian family, and held extenſive landed eſtates in Eſſex and Suffolk. He ſurvived the Queen only eight months, dying November 30th, 1603.

ILBERT'S monumental work, the *De Magnete*, publiſhed in 1600, marks an era in magnetic ſcience. For ſome four hundred years the employment of the magnetic needle in navigation had been known both in Northern and Southern Europe. While it is poſſible that the primitive uſe of the loadſtone may be aſcribed to the Baltic, it is certain that the employment of a pivotted needle, and the addition of a roſe of the winds as a compaſs card both originated in the Mediterranean. The pivotted needle is deſcribed in the Epiſtle of Peter Peregrinus, written in 1269; while the earlieſt known compaſs-card marked with the initials of the names of the winds is that aſcribed to Jachobus Giraldis, of 1426, in the Biblioteca Marciana in Venice. The manner of uſe in Elizabethan times of the loadſtone and of the compaſs may be gathered from Olaus Magnus (*Hiſtoria de Gentibus Septentrionalibus*, 1555), from Pedro de Medina (*Arte de Nauegar*, 1545), Mar-

tinus Cortes (*Breve compendio de la ſphera*, 1556), Blundevile (*Exerciſes*, 1594), Norman (*Newe Attractive*, 1581), Borough (*A diſcours of the Variation of the Cumpas*, 1581), Pedro Nuñez (*Inſtrumenta Artis Navigandi*, 1592), Barlow (*The Navigators Supply*, 1597), Nautonier (*Mécometrie de l'Eyman*, 1602), and Stevin (*Die Havenvinding*, 1599).

At the time when ſteering by the compaſs was introduced into navigation, the compaſs pointed in Middle Europe ſo nearly truly to the north that with the rough inſtrumental appliances at hand its deviation from the true north was ſeldom noticed, or if noticed aſcribed to ſome error in the ſetting of the needle. Later the compaſs-makers began to ſet their needles ſlightly aſkew beneath the card, according to the variation in the place of origin. Norman (1581) ſtates that thoſe uſed in the Levant, made in Sicily, Genoa, or Venice, had the needles ſtraight, while thoſe uſed in Denmark and Flanders had them ſet at three-quarters of a point, or a whole point, to the eaſtward; while thoſe made in Spain, Portugal, France, and England, had the needles ſet half a point to the eaſt. Thoſe for Ruſſia were ſet at "three ſeconds of a point." Gilbert denounced theſe devices as tending to obſcure the true facts. Gradually it became recognized, prob-

ably after the voyage of Columbus, when the manifeſt change in the declination of the needle nearly cauſed mutiny of the ſailors, that the direction of the needle differs at different places; and accordingly navigators began to collect data. The record of the voyage of Columbus ſtates that during his ſecond voyage in 1496 he uſed for ſteering the obſervations made on the declination during his firſt voyage. The "ſecret" of Sebaſtian Cabot, which he declared when dying to be a divine revelation to him, can have been little elſe than the idea of uſing in navigation the local declinations of the compaſs. On the other hand, Pedro de Medina flatly denied the exiſtence of the declination, adding that if the compaſs did not ſhow the pole, the fault lay in the defective conſtruction of the compaſs itſelf. Columbus had found a point $2\frac{1}{2}^{\circ}$ eaſt of Corvo, in the Azores, where there was "no variation," and other navigators explored the "agonic" lines which croſſed the Atlantic and the Indian ocean. According to Humboldt, Alonzo de Santa Cruz in 1530 conſtructed the firſt general variation chart. But along with this development of practical intereſt in the ſubject there grew up a crop of wild legends to account for the irregularities obſerved. The reaſon why the compaſs

needle pointed north, and the reaſon why it did not point truly north, were alike proclaimed to be due to the ſtars, to the influence of ſpirits, or to the exiſtence of loadſtone mountains of uncertain locality and of fabulous power. The old traditions of the Arabian Nights, dreſſed in a newer ſetting, found themſelves juſtified by the inſertion in maps of loadſtone rocks, the poſition of which changed at the fancy of the chartographer. Ptolemy had located them in the Manioles; Olaus Magnus declared them to be under the pole; Garzias ab Horto ſituated them in the region of Calcutta. The map of Johann Ruyſch, which adorned the edition of Ptolemy, publiſht at Rome in 1508, ſhowed four magnetic iſlands in the Arctic Circle. Martinus Cortes placed the loadſtone mountains in Sarmatia. Mercator in his great chart depicted two great rocks riſing from the ſea to the north of eaſtern Siberia, one being drawn on the ſuppoſition that at St. Michael the compaſs points due north, while the other is further north on the ſuppoſition that the compaſs points due north at Corvo. The map of Cornelius Wytfliet, 1597, ſhows the ſame phantom iſlands. Blundevile, writing in 1594 of the now loſt map of Peter Plancius, mentions that he ſets down the pole of

the loadſtone ſomewhat to ſouthward of the iſlands that lie eaſt of Groynelande.

Meantime another ſignificant fact had been diſcovered in 1576 by Robert Norman, of Limehouſe, compaſs-maker, namely, the tendency of the magnetized needle to dip its northern end downwards. Noticing this as a circumſtance that occaſioned him ſome trouble in the conſtruction of his compaſſes, he thereupon deviſed a dipping-needle, and meaſured the dip, "which for this Cyty of London I finde by exact obſeruations to be about 71 degrees 50 mynutes." He attributed both the declination and the dip of the needle to the exiſtence of a "poynt reſpective," which the needle reſpected or indicated, but toward which it was not attracted. The firſt authoritative treatiſe on the variation of the compaſs was the tract by William Borough, comptroller to the Navy, who in 1580 found an eaſtward declination of 11° 15′ at Limehouſe. Borough had himſelf travelled in northern regions and had found at Vaigats a weſterly declination of 7 degrees, whereas by Norman's theory of the reſpective point there ſhould have been an eaſterly declination of 49° 22′. The great navigators were continually bringing home freſh information. Drake, Lynſchoten, Cavendiſh,

Hariot all contributed; as did leſſer men ſuch as Abraham Kendall, ſailing-maſter to Sir Robert Dudley (the *ſoi-diſant* Duke of Northumberland), and afterward companion of Drake in his laſt voyage. Teachers of navigation ſuch as Simon Stevin of Bruges and Edward Wright, lecturer to the Eaſt India Company, might record and tabulate: but a maſter-mind was wanting to forge ſome larger and conſiſtent doctrine which ſhould afford a graſp of the whole ſubject. Such an one aroſe in Dr. William Gilbert. Nurtured, as we have ſeen, in the Cambridge which had ſo recently been the home of Linacre and of Kaye—the Kaye who founded Caius College—Gilbert had, during his ſubſequent ſojourn in Italy, converſed with all the learned men of his time. He had experimented on the magnet with Fra Paolo Sarpi: he had, there is reaſon to think, met Giordano Bruno: he was the friend and correſpondent of Giovanni Franceſco Sagredo. Being a man of means and a bachelor, he ſpent money freely upon books, maps, inſtruments, minerals, and magnets. For twenty years he experimented ceaſeleſſly, and read, and wrote and ſpeculated, and teſted his ſpeculations by new experiments. For eighteen years he kept beſide him the manuſcript of his treatiſe, which in the

year 1600 ſaw the light under the title of *De Magnete*, to which was added the ſub-title: *magneticiſque corporibus, et de magno magnete tellure, phyſiologia nova.* That which Gilbert had in fact perceived, and which none before him had glimpſed even dimly, was that the globe of the earth itſelf acted as a great loadſtone, and that the tendency of the needle to point in a polar direction was due to the globe acting as a whole. So he boldly put into his title-page the ſtatement that his new philoſophy was concerning the great magnet the earth: and in chapter after chapter he ſet himſelf to deſcribe the experiments upon which he founded his famous induction. The phraſe *terreſtrial magnetiſm* does not occur in any of the prior treatiſes, becauſe the idea had not preſented itſelf. Gilbert piled proof upon proof, ſometimes moſt cogently, as when he conſtructed loadſtone globes, or *terrellas* to ſerve as magnetic models of the earth; ſometimes with indifferent logic, as when he pointed to the iron ore in the earth and reaſoned that the magnet tended to conform to (*i.e.* turn itſelf toward) the homogenic ſubſtance of the body from which it had been dug. The local deviations of the compaſs he ſought to account for by the irregularities of the earth's cruſt, and maintained

that the compaſs tended always, at places off the coaſt of a continent, to be deflected ſomewhat toward that continent. His ſyllogiſm was baſed on the fact that at that date all the way up the Atlantic ſeaboard of Europe, from Morocco to Norway, the variation was eaſtward. He argued that this was a univerſal law. But even within one generation, as may be ſeen in *Purchas his Pilgrims*, in the narrative of the voyage of Bylot and Baffin, the generality of the law was queſtioned. Gilbert reaſoned on ſuch knowledge as he had, and this did not include any notion of the ſecular changes in the declination. In his time, as he tells us, the variation of the compaſs at London was $11\frac{1}{3}$ degrees. What he did not know was that this was a diminiſhing quantity which in fifty-ſeven years would be reduced to zero, to be ſucceeded by a weſtward declination that would laſt for nearly three hundred years. For the facts as known in the thirty years ſucceeding Gilbert's death, ſee the remarkable and ſcarce volume of Gellibrand: *A Diſcourſe Mathematical on the Variation of the Magneticall Needle* (1635).

Gilbert's treatiſe is a ſkilful literary achievement in which there is no trace to reveal whether any part was written before the reſt. It is divided

ſyſtematically into ſix books. The ſixth book only appears to ſuffer from ſome incompleteneſs. It relates not ſo much to the magnet as to the Copernican theory of the univerſe, which doctrine Gilbert had eagerly eſpouſed, and which he was the firſt in England to proclaim. It is known from a letter to Barlow, printed in 1616, that he intended to add to it certain chapters deſcriptive of ſome of his inſtruments, but he had not completed theſe before his death. The firſt book treats of hiſtoric accounts of the loadſtone, of its origin and properties, of iron ores in general, and of the fables and vain opinions which in the handling of Paracelſus and of the ſchoolmen had grown up around the magnet. The ſecond book is on the magnetic motions, and primarily on the attractions and repulſions between loadſtones, between loadſtone and iron, and between magnetic needles. In this book occurs the notable digreſſion upon the ſubject of amber and the electric forces of amber and of other ſubſtances which when rubbed ſhow, as he diſcovered, ſimilar electrical powers. An analyſis of this part, and a ſummary of Gilbert's electrical diſcoveries will be found in the Notes printed for the Gilbert Club to accompany the Engliſh tranſlation (1900) of the *De Magnete*.

After this digreſſion Gilbert returns to the attractive properties of the loadſtone, and to the way they are affected by giving it different ſhapes. In the courſe of this enquiry, he announces his diſcovery of the augmentation of the power of the loadſtone by arming it with iron caps, an invention which cauſed Galileo to ſay: "I extremely praiſe, admire, and envy this author for that a conception ſo ſtupendous ſhould come into his mind. I think him moreover worthy of extraordinary applauſe for the many new and true obſervations that he has made." Gilbert further pointed out that the loadſtone is ſurrounded by a ſort of atmoſphere or "orbe of virtue" within which the magnetical effects can be obſerved. Book 3, on the directive force of the magnet, is full of moſt inſtructive experiments, in which the terrella figures largely, relating to the queſtion how one magnet influences another and tends to make it point toward it. All this was leading up to the theory of terreſtrial magnetiſm; for we find him naming the parts of his loadſtone globes with poles, equator and meridians. In this book he dilates on the obſervation that vertical iron rods, ſuch as the finial on the Church of St. John at Rimini, ſpontaneouſly acquired magnetic pro-

perties. This he traced to the influence of the earth, and demonſtrated the effect by magnetizing iron bars by ſimply hammering them on the anvil while they lay in a north and ſouth poſition. Book 4 deals with the Declination, or, as it was then called, the variation of the compaſs. He diſcuſſes its obſervation and meaſurement, the influence of iſlands, the reſults obtained by travellers to diſtant parts, Nova Zembla, the Guinea coaſt, the Canary Iſles, Florida, Virginia, Cape Race, and Brazil. Then he recounts his experiments with terrellas having uneven ſurfaces to repreſent the irregularities of the earth's cruſt. He points out errors ariſing from the fallacious practice of ſetting the needle obliquely under the card. He conſiders in ſeparate chapters the variations in Nova Zembla, in the Pacific, in the Mediterranean, and in the Eaſtern Ocean. The fifth book is on the Dip. Gilbert ſeized with avidity on Norman's diſcovery of this effect, and deviſed an improved form of dipping-needle. He experimented on the dip of compaſs-needles placed at different points over his terrella, and evolved a theory on the proportion which he conceived to exiſt between the latitude and the dip. Arguing from all too imperfect data, he propounded the view that the dip was the ſame

in any given latitude; and propoſed that ſeamen ſhould aſcertain their latitudes by ſimply obſerving the dip. He was aware that local irregularities might occur, as they do in the declination; but was not deterred by this knowledge from propounding his theory with much circumſtance and conſiderable geometrical ſkill. After the publication of his book he developed the theory ſtill further and gave it to Blundevile for publication. At Gilbert's ſuggeſtion Briggs of Greſham College calculated out a table of dip and latitude. It was, however, ſoon found that the facts deviated more or leſs widely from the theory. Further obſervations in other lands ſhowed the method to be impracticable; and Gilbert's hope to give to the mariner a magnetic meaſure of latitude remained unfulfilled. Book 5 cloſes with an eloquent paſſage in which Gilbert affirmed the neo-Platonic doctrine of the animate nature of the univerſe, and aſſerted that Thales was right when he held (as Ariſtotle relates in the *De Anima*) that the loadſtone was animate, being part of and indeed the choice offspring of its animate mother the earth. Book 6, as already mentioned, is devoted to Copernican ideas, and contains Gilbert's one contribution to the ſcience of Aſtronomy, in his re-

mark that the fixed ſtars (previouſly regarded as fixed in the eighth of the celeſtial ſpheres at one common diſtance from the central earth) were in reality ſet in the heavens at various diſtances from the earth.

From this brief analyſis it will be ſeen that Gilbert's claims to eminence reſt not upon any particular diſcovery or invention, but upon his having built up a whole experimental magnetic philoſophy on a truly ſcientific baſis, in place of the vague and wild ſpeculations which had previouſly been accepted. By his magnificent generalization from the ſmall ſcale models to the globe itſelf, ſupported from point to point by experimental reſearches, he created the ſcience of terreſtrial magnetiſm. If from the imperfection of the data at his diſposal he fell into ſundry errors of detail, he yet founded the method of philoſophizing by which thoſe errors were in due time corrected. And if for nothing elſe than his maſterly vindication of ſcientific method, and his reſcue of the ſubject of magnetiſm from the pedantry and charlatanry into which in the preceding ages it had lapſed, his memory muſt be held in high honour.

Alas that of the perſonality of ſo great a man ſo

little ſhould be known. A brief but characteriſtic biography of him is enſhrined by old Fuller in his *Worthies*. The poet Dryden, and the epigrammatiſt Owen, celebrated him in ſtill briefer verſe. His portrait, which hung for nigh two hundred years in the Schools Gallery, at Oxford, diſappeared a century ago, leaving only a poor engraving to perpetuate his ſcholarly countenance. Doubtleſs he is one of the four phyſicians depicted by the pencil of Camden in his famous cartoon (now in the Britiſh Muſeum), as walking in the funeral proceſſion of Queen Elizabeth. Of his handwriting not a veſtige was known until about five years ago, when a ſignature was unearthed in the Record Office. Subſequently four ſignatures were found in the books of St. John's College; and recently there has come to light a volume of Ariſtotle bearing Gilbert's own marginal notes. His will lies at Somerſet Houſe, but it is only a copy. Of his fine collection of minerals and loadſtones, which with his maps, books, manuſcripts, and correſpondence with Sarpi and Sagredo and others, he bequeathed to the College of Phyſicians, nothing remains: they periſht in the Great Fire of London. In a quiet corner of the City of Colcheſter ſtands the quaint old houſe where he lived, and where,

according to local tradition, he once received the Queen. And hard by it is the church of Holy Trinity, in which a mural tablet records his virtues and marks his laſt reſting place. But his true monument is the immortal treatiſe in which he laid the foundations of terreſtrial magnetiſm and of the experimental ſcience of electricity.

To the names of the men who made great the age of Queen Elizabeth, who added luſtre to the England over which ſhe ruled, and made it famous in foreign diſcovery, in ſea-craft, in literature, in poetry, and in drama, muſt be joined that of the man who equally added luſtre in ſcience, Doctor William Gilbert.

This diſcourſe on William Gilbert and terreſtrial magnetiſm in the time of Queen Elizabeth was delivered by Silvanus P. Thompſon at the meeting of the Royal Geographical Society on March twenty-third MDCCCCIII on the occaſion of the tercentenary of the death of Queen Elizabeth, and is now printed by Charles Whittingham and Company at the Chiſwick Preſs.