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VVILLIAM GILBERT

OF COLCHESTER,

PHYSICIAN OF

LONDON.

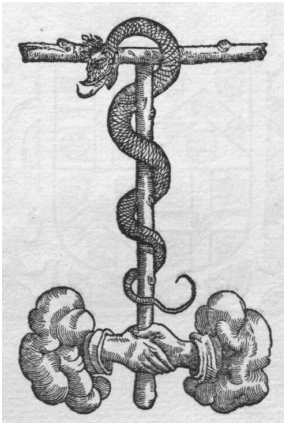
ON THE MAGNET, MAGNETICK

BODIES ALSO, AND ON

the great magnet the earth; a new Physiology,

demonstrated by many arguments

& experiments.



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PREFACE TO THE CANDID READER, STUDIOUS OF THE MAGNETICK PHILOSOPHY.

Clearer proofs, in the discovery of secrets, and in the investigation of the hidden causes of things, being afforded by trustworthy experiments and by demonstrated arguments, than by the probable guesses and opinions of the ordinary professors of philosophy: so, therefore, that the noble substance of that great magnet, our common mother (the earth), hitherto quite unknown, and the conspicuous and exalted powers of this our globe, may be the better understood, we have proposed to begin with the common magnetick, stony, and iron material, and with magnetical bodies, and with the nearer parts of the earth which we can reach with our hands and perceive with our senses; then to proceed with demonstrable magnetick experiments; and so penetrate, for the first time, into the innermost parts of the earth. For after we had, in order finally to learn the true substance of the globe, seen and thoroughly examined many of those things which have been obtained from mountain heights or ocean depths, or from the profoundest caverns and from hidden mines: we applied much prolonged labour on investigating the magnetical forces; so wonderful indeed are they, compared with the forces of all other minerals, surpassing even the virtues of all other bodies about us. Nor have we found this our labour idle or unfruitful; since daily during our experimenting, new and unexpected properties came to light; and our Philosophy hath grown so much from the things diligently observed, that we have attempted to expound the interior parts of the terrene globe, and its native substance, upon magnetick principles; and to reveal to men the earth (our common mother), and to point it out as if with the finger, by real demonstrations and by experiments manifestly apparent to the senses. And as geometry ascends from sundry very small and very easy principles to the greatest and most difficult; by which the wit of man climbs above the firmament: so our magnetical doctrine and science first sets forth in convenient order the things which are less obscure; from these there come to light others that are more remarkable; and at length in due order there are opened the concealed and most secret things of the globe of the earth, and the causes are made known of those things which, either through the ignorance of the ancients or the neglect of moderns, have remained unrecognized and overlooked. But why should I, in so vast an Ocean of Books by which the minds of studious men are troubled and fatigued, through which very foolish productions the world and unreasoning men are intoxicated, and puffed up, rave and create literary broils, and while professing to be philosophers, physicians, mathematicians and astrologers, neglect and despise men of learning: why should I, I say, add aught further to this so-perturbed republick of letters, and expose this noble philosophy, which seems new and incredible by reason of so many things hitherto unrevealed, to be damned and torn to pieces by the maledictions of those who are either already sworn to the opinions of other men, or are foolish corruptors of good arts, learned idiots, grammatists, sophists, wranglers, and perverse little folk? But to you alone, true philosophizers, honest men, who seek knowledge not from books only but from things themselves, have I addressed these magnetical principles in this

new sort of Philosophizing. But if any see not fit to assent to these self-same opinions and paradoxes, let them nevertheless mark the great array of experiments and discoveries (by which notably every philosophy flourisheth), which have been wrought out and demonstrated by us with many pains and vigils and expenses. In these rejoice, and employ them to better uses, if ye shall be able. I know how arduous it is to give freshness to old things, lustre to the antiquated, light to the dark, grace to the despised, credibility to the doubtful; so much the more by far is it difficult to win and establish some authority for things new and unheard-of, in the face of all the opinions of all men. Nor for that do we care, since philosophizing, as we deemed, is for the few. To our own discoveries and experiments we have affixed asterisks, larger and smaller, according to the importance and subtlety of the matter. Whoso desireth to make trial of the same experiments, let him handle the substances, not negligently and carelessly, but prudently, deftly, and in the proper way; nor let him (when a thing doth not succeed) ignorantly denounce our discoveries: for nothing hath been set down in these books which hath not been explored and many times performed and repeated amongst us. Many things in our reasonings and hypotheses will, perchance, at first sight, seem rather hard, when they are foreign to the commonly received opinion; yet I doubt not but that hereafter they will yet obtain authority from the demonstrations themselves. Wherefore in magnetical science, they who have made most progress, trust most in and profit most by the hypotheses; nor will anything readily become certain to any one in a magnetical philosophy in which all or at least most points are not ascertained. This nature-knowledge is almost entirely new and unheard-of, save what few matters a very few writers have handed down concerning certain common magnetical powers. Wherefore we but seldom quote antient Greek authors in our support, because neither by using greek arguments nor greek words can the truth be demonstrated or elucidated either more precisely or more significantly. For our doctrine magnetical is at variance with most of their principles and dogmas. Nor have we brought to this work any pretence of eloquence or adornments of words; but this only have we done, that things difficult and unknown might be so handled by us, in such a form of speech, and in such words as are needed to be clearly understood: Sometimes therefore we use new and unusual words, not that by means of foolish veils of vocabularies we should cover over the facts with shades and mists (as Alchemists are wont to do) but that hidden things which have no name, never having been hitherto perceived, may be plainly and correctly enunciated. After describing our magnetical experiments and our information of the homogenick parts of the earth, we proceed to the general nature of the whole globe; wherein it is permitted us to philosophize freely and with the same liberty which the Egyptians, Greeks, and Latins formerly used in publishing their dogmas: whereof very many errors have been handed down in turn to later authors: and in which smatterers still persist, and wander as though in perpetual darkness. To those early forefathers of philosophy, Aristotle, Theophrastus, Ptolemy, Hippocrates, and Galen, let due honour be ever paid: for by them wisdom hath been diffused to posterity; but our age hath detected and brought to light very many facts which they, were they now alive, would gladly have accepted. Wherefore we also have not hesitated to expound in demonstrable hypotheses those things which we have discovered by long experience. Farewell. {iij}

TO THE MOST EMINENT AND LEARNED MAN

Dr. William Gilbert,

a distinguished Doctor of Medicine amongst the

Londoners, and Father of Magnetick Philosophy,

an Encomiastic Preface of Edward Wright

on the subject of these books

Magnetical.

hould there by chance be any one, most eminent Sir, who reckons as of small account these magnetical books and labours of yours, and thinks these studies of yours of too little moment, and by no means worthy enough of the attention of an eminent man devoted to the weightier study of Medicine: truly he must deservedly be judged to be in no common degree void of understanding. For that the use of the magnet is very important and wholly admirable is better known for the most part to men of even the lowest class than to need from me at this time any long address or commendation. Nor truly in my judgment could you have chosen any topick either more noble or more useful to the human race, upon which to exercise the strength of your philosophic intellect; since indeed it has been brought about by the divine agency of this stone, that continents of such vast circuit, such an infinite number of lands, islands, peoples, and tribes, which have remained unknown for so many ages, have now only a short time ago, almost within our own memory, been quite easily discovered and quite frequently explored, and that the circuit of the whole terrestrial globe also has been more than once circumnavigated by our own countrymen, Drake and Cavendish; a fact which I wish to mention to the lasting memory of these men. For by the pointing of the iron touched by a loadstone, the points of South, North, East, and West, and the other quarters of the world are made known to navigators even under an overcast sky and in the darkest night; so that thus they

always very easily understand to which point of the world they ought to direct their ship's course; which before the discovery of this wonderful virtue of the magnetick βορεοδείξις *was clearly impossible. Hence in old times (as is established in histories), an incredible anxiety and immense danger was continually threatening sailors; for at the coming on of a tempest and the obscuring of the view of sun and stars, they were left entirely in ignorance whither they were making; nor could they find out this by any reasoning or skill. With what joy then may we suppose them to have been filled, to what feelings of delight must all shipmasters have given utterance, when that index magnetical first offered itself to them as a most sure guide, and as it were a Mercury, for their journey? But neither was this sufficient for this magnetical Mercury; to indicate, namely, the right way, and to point, as it were, a finger in the direction toward which the course must be directed; it began also long ago to show distinctly the distance of the place toward which it* {iiij} *points. For since the index magnetical does not always in every place look toward the same point of the North, but deviates from it often, either toward the East or toward the West, yet always has the same deviation in the same place, whatever the place is, and steadily preserves it; it has come about that from that deviation, which they call variation, carefully noticed and observed in any maritime places, the same places could afterwards also be found by navigators from the drawing near and approach to the same variation as that of these same places, taken in conjunction with the observation of the latitude. Thus the Portuguese in their voyages to the East Indies had the most certain indications of their approach to the Cape of Good Hope; as appears from the narrations of Hugo van Lynschoten and of the very learned Richard Hakluyt, our countryman. Hence also the experienced skippers of our own country, not a few of them, in making the voyage from the Gulf of Mexico to the islands of the Azores, recognized that they had come as near as possible to these same islands; although from their sea-charts they seemed to be about six hundred British miles from them. And so, by the help of this magnetick index, it would seem as though that geographical problem of finding the longitude, which for so many centuries has exercised the intellects of the most learned Mathematicians, were going to be in some way satisfied; because if the variation for any maritime place whatever were known, the same place could very readily be found afterward, as often as was required, from the same variation, the latitude of the same place being not unknown.*

It seems, however, that there has been some inconvenience and hindrance connected with the observation of this variation; because it cannot be observed excepting when the sun or the stars are shining. Accordingly this magnetick Mercury of the sea goes on still further to bless all shipmasters, being much to be preferred to Neptune himself, and to all the sea-gods and goddesses; not only does it show the direction in a dark night and in thick weather, but it also seems to exhibit the most certain indications of the latitude. For an iron index, suspended on its axis (like a pair of scales), with the most delicate workmanship so as to balance in æquilibrio, and then touched and excited by a loadstone, dips to some fixed and definite point beneath the horizon (in our latitude in London, for example, to about the seventy-second degree), at which it at length comes to rest. But under the æquator itself, from that admirable agreement and congruency which, in almost all and singular magnetical experiments, exists between the earth itself and a terrella (that is, a globular loadstone), it seems exceedingly likely (to say the very least), and indeed more than probable, that the same index (again stroked with a loadstone) will remain in æquilibrio in an horizontal position. Whence it is evident that this also is very probable, that in an exceedingly small progress from the South toward the North (or contrariwise) there will be at least a sufficiently perceptible change in that declination; so that from that declination in any place being once carefully observed along with the latitude, the same place and the same latitude may be very easily recognized afterward, even in the darkest night and in the thickest mist by a declination instrument. Wherefore to bring our oration at length back to you, most eminent and learned Dr. Gilbert (whom I gladly recognize as my teacher in this magnetick philosophy), if these books of yours on the Magnet had contained nothing else, excepting only this finding of latitude from magnetick declination, by you now first brought to light, our shipmasters, Britains, French, Belgians, and Danes, trying to enter the British Channel or the Straits of Gibraltar from the Atlantick Ocean in dark weather, would still most deservedly judge them to be valued at no small sum of gold. But that discovery of yours about the whole globe of the earth being magnetical, although perchance it will seem to many "most paradoxical," producing even a feeling of astonishment, has yet been so firmly defended by you at all points and confirmed by so many experiments so apposite and appropriate to the matter in hand, in Bk. 2, chap. 34; Bk. 3, chap. 4 and 12; and in almost the whole of the fifth book, that no room is left for doubt or contradiction. I come therefore to the cause of the magnetick variation, which hitherto has distracted the minds of all the learned; for which no mortal has ever adduced a more probable reason than that which has now been set forth by you for the first time in these books of yours on the Magnet. The ὀρθοβορεοδείξις *of the index magnetical in the middle of the ocean, and in the middle of continents (or at least in the middle of their stronger and more lofty parts), its inclining near the shore toward those same parts, even by sea and by land, agreeing with the experiments Bk. 4, chap. 2, on an actual terrella (made after the likeness of the terrestrial globe, uneven, and rising up in certain parts, either weak or wanting in firmness, or imperfect in some other way),—this inclination having been proved, very certainly demonstrates the probability that that variation is nought else than a certain deviation of the magnetick needle toward those parts of the earth that are more vigorous and more prominent. Whence the reason is readily established of that irregularity which is often perceived in the magnetick variations, arising from the inæquality and irregularity of those eminences and of the terrestrial forces. Nor of a surety have I any doubt, that all those even who have either imagined or admitted points attractive or points respective in the sky or the earth, and those who have imagined magnetick mountains, or rocks, or poles, will immediately begin to waver as soon as they have perused these books of*

yours on the Magnet, and willingly will march with your opinion. Finally, as to the views which you discuss in regard to the circular motion of the earth and of the terrestrial poles, although to some perhaps they will seem most supposititious, yet I do not see why they should not gain some favour, even among the very men who do not recognize a sphærical motion of the earth; since not even they can easily clear themselves from many difficulties, which necessarily follow from the daily motion of the whole sky. For in the first place it is against reason that that should be {v}
effected by many causes, which can be effected by fewer; and it is against reason that the whole sky and all the sphæres (if there be any) of the stars, both of the planets and the fixed stars, should be turned round for the sake of a daily motion which can be explained by the mere daily rotation of the earth. Then whether will it seem more probable, that the æquator of the terrestrial globe in a single second (that is, in about the time in which any one walking quickly will be able to advance only a single pace) can accomplish a quarter of a British mile (of which sixty equal one degree of a great circle on the earth), or that the æquator of the primum mobile *in the same time should traverse five thousand miles with celerity ineffable; and in the twinkling of an eye should fly through about five hundred British miles, swifter than the wings of lightning, if indeed they maintain the truth who especially assail the motion of the earth). Finally, will it be more likely to allow some motion to this very tiny terrestrial globe; or to build up with mad endeavour above the eighth of the fixed sphæres those three huge sphæres, the ninth (I mean), the tenth, and the eleventh, marked by not a single star, especially since it is plain from these books on the magnet, from a comparison of the earth and the terrella, that a circular motion is not so alien to the nature of the earth as is commonly supposed. Nor do those things which are adduced from the sacred Scriptures seem to be specially adverse to the doctrine of the mobility of the earth; nor does it seem to have been the intention of Moses or of the Prophets to promulgate any mathematical or physical niceties, but to adapt themselves to the understanding of the common people and their manner of speech, just as nurses are accustomed to adapt themselves to infants, and not to go into every unnecessary detail. Thus in Gen. i. v. 16, and Psal. 136, the moon is called a great light, because it appears so to us, though it it is agreed nevertheless by those skilled in astronomy that many of the stars, both of the fixed and wandering stars, are much greater. Therefore neither do I think that any solid conclusion can be drawn against the earth's mobility from Psal. 104, v. 5; although God is said to have laid the foundations of the earth that it should not be removed for ever; for the earth will be able to remain evermore in its own and self-same place, so as not to be moved by any wandering motion, nor carried away from its seat (wherein it was first placed by the Divine artificer). We, therefore, with devout mind acknowledging and adoring the inscrutable wisdom of the triune Divinity (having more diligently investigated and observed his admirable work in the magnetical motions), induced by philosophical experiments and reasonings not a few, do deem it to be probable enough that the earth, though resting on its centre as on an immovable base and foundation, nevertheless is borne around circularly.*

But passing over these matters (concerning which I believe no one has ever demonstrated anything with greater certainty), without any doubt those matters which you have discussed concerning the causes of the variation and of the magnetick dip below the horizon, not to mention many other matters, which it would take too long to speak of here, will gain very great favour amongst all intelligent men, and especially (to speak after the manner of the Chemists) amongst the sons of the magnetick doctrine. Nor indeed do I doubt that when you have published these books of yours on the Magnet, you will excite all the diligent and industrious shipmasters to take no less care in observing the magnetick declination beneath the horizon than the variation. Since (if not certain) it is at least probable, that the latitude itself, or rather the effect of the latitude, can be found (even in very dark weather) much more accurately from that declination alone, than can either the longitude or the effect of the longitude from the variation, though the sun itself is shining brightly or all the stars are visible, with the most skilful employment likewise of all the most exact instruments. Nor is there any doubt but that those most learned men, Peter Plancius (not more deeply versed in Geography than in observations magnetical), and Simon Stevinus, the most distinguished mathematician, will rejoice in no moderate degree, when they first see these magnetical books of yours, and observe their λιμενευρετική, *or* Haven-finding Art, *enlarged and enriched by so great and unexpected an addition; and without doubt they will urge all their own shipmasters (as far as they can) to observe also everywhere the magnetick declination below the horizon no less than the variation. May your Magnetical Philosophy, therefore, most learned Dr. Gilbert, come forth into the light under the best auspices, after being kept back not till the ninth year only (as Horace prescribes), but already unto almost a second nine, a philosophy rescued at last by so many toils, studyings, watchings, with so much ingenuity and at no moderate expense maintained continuously through so many years, out of darkness and dense mist of the idle and feeble philosophizers, by means of endless experiments skilfully applied to it; yet without neglecting anything which has been handed down in the writings of any of the ancients or of the moderns, all which you did diligently peruse and perpend. Do not fear the boldness or the prejudice of any supercilious and base philosophaster, who by either enviously calumniating or stealthily arrogating to himself the investigations of others seeks to snatch a most empty glory. Verily*

> Envy detracts from great Homer's genius;

but

> Whoever thou art, Zoilus, thou hast thy name from him.

May your new physiology of the Magnet, I say (kept back for so many years), come forth now at

length into the view of all, and your Philosophy, never to be enough admired, concerning the great Magnet (that is, the earth); for, believe me

(If there is any truth in the forebodings of seers),

these books of yours on the Magnet will avail more for perpetuating the memory of your name than the monument of any great Magnate placed upon your tomb.

{vj}

Interpretation of certain words.[1]

Terrella, a globular loadstone.

Verticity, polar vigour, not περιδίνησις but περιδίνεισιος δύναμις: not a vertex or πόλος but a turning tendency.

Electricks, things which attract in the same manner as amber.

Excited Magnetick, that which has acquired powers from the loadstone.

Magnetick Versorium, a piece of iron upon a pin, excited by a loadstone.

Non-magnetick Versorium, a versorium of any metal, serving for electrical experiments.

Capped loadstone, which is furnished with an iron cap, or snout.

Meridionally, that is, along the projection of the meridian.

Paralleletically, that is, along the projection of a parallel.

Cusp, tip of a versorium excited by the loadstone.

Cross, sometimes used of the end that has not been touched and excited by a loadstone, though in many instruments both ends are excited by the appropriate termini of the stone.

Cork, that is, bark of the cork-oak.

Radius of the Orbe of the Loadstone, is a straight line drawn from the summit of the orbe of the loadstone, by the shortest way, to the surface of the body, which, continued, will pass through the centre of the loadstone.

Orbe of Virtue, is all that space through which the Virtue of any loadstone extends.

Orbe of Coition, is all that space through which the smallest magnetick is moved by the loadstone.

Proof, for a demonstration shown by means of a body.

Magnetick Coition: since in magnetick bodies, motion does not occur by an attractive faculty, but by a concourse or concordance of both, not as if there were an ἑλκτικὴ δύναμις of one only, but a συνδρομή of both; there is always a coition of the vigour: and even of the body if its mass should not obstruct.

Declinatorium, a piece of Iron capable of turning about an axis, excited by a loadstone, in a declination instrument.

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WILLIAM GILBERT

ON THE LOADSTONE, BK. I.

CHAP. I.

ANCIENT AND MODERN WRITINGS
on the Loadstone, with certain matters of mention only,
various opinions, & vanities.

t an early period, while philosophy lay as yet rude and uncultivated in the mists of error and ignorance, few were the virtues and properties of things that were known and clearly perceived: there was a bristling forest of plants and herbs, things metallick were hidden, and the knowledge of stones was unheeded. But no sooner had the talents and toils of many brought to light certain commodities necessary for the use and safety of men, and handed them on to others (while at the same time reason and experience had added a larger hope), than a thorough examination began to be made of forests and fields, hills and heights; of seas too, and the depths of the waters, of the bowels of the earth's body; and all things began to be looked into. And at length by good luck the magnet-stone was discovered in iron lodes, probably by smelters of iron or diggers of metals. This, on being handled by metal folk, quickly displayed that powerful and strong attraction for iron, a virtue not latent and obscure, but easily proved by all, and highly praised and commended. And in after time when it had emerged, as it were out of darkness and deep dungeons, and had become dignified of men on account of its strong and amazing attraction for iron, many philosophers as well as physicians of ancient days discoursed of it, in short celebrated, as it were, its memory only; as for instance

Plato in the *Io*[2], Aristotle in the *De Anima*[3], in Book I. only, Theophrastus the Lesbian, Dioscorides, C. Plinius Secundus, and Julius Solinus[4]. As handed down by them the loadstone merely attracted iron, the rest of its virtues were all undiscovered. But that the story of the loadstone might not appear too bare and too brief, to this singular and sole known quality there {2} were added certain figments and falsehoods, which in the earliest times, no less than nowadays, used to be put forth by raw smatterers and copyists to be swallowed of men. As for instance, that if a loadstone be anointed with garlick, or if a diamond be near, it does not attract iron[5]. Tales of this sort occur in Pliny, and in Ptolemy's *Quadripartitum*; and the errors have been sedulously propagated, and have gained ground (like ill weeds that grow apace) coming down even to our own day, through the writings of a host of men, who, to fill put their volumes to a proper bulk, write and copy out pages upon pages on this, that, and the other subject, of which they knew almost nothing for certain of their own experience. Such fables of the loadstone even Georgius Agricola himself, most distinguished in letters, relying on the writings of others, has embodied as actual history in his books *De Natura Fossilium*. Galen noted its medicinal power in the ninth book of his *De Simplicium Medicamentorum Facultatibus*, and its natural property of attracting iron in the first book of *De Naturalibus Facultatibus*; but he failed to recognize the cause, as Dioscorides before him, nor made further inquiry. But his commentator Matthiolus repeats the story of the garlick and the diamond, and moreover introduces Mahomet's shrine vaulted with loadstones[6], and writes that, by the exhibition of this (with the iron coffin hanging in the air) as a divine miracle, the public were imposed upon. But this is known by travellers to be false. Yet Pliny relates that Chinocrates the architect had commenced to roof over the temple of Arsinoe at Alexandria with magnet-stone[7], that her statue of iron placed therein might appear to hang in space. His own death, however, intervened, and also that of Ptolemy, who had ordered it to be made in honour of his sister. Very little was written by the ancients as to the causes of attraction of iron; by Lucretius and others there are some short notices; others only make slight and meagre mention of the attraction of iron: all of these are censured by Cardan for being so careless and negligent in a matter of such importance and in so wide a field of philosophizing; and for not supplying an ampler notion of it and a more perfect philosophy: and yet, beyond certain received opinions and ideas borrowed from others and ill-founded conjectures, he has not himself any more than they delivered to posterity in all his bulky works any contribution to the subject worthy of a philosopher. Of modern writers some set forth its virtue in medicine only, as [8]Antonius Musa Brasavolus, Baptista Montanus, Amatus Lusitanus, as before them Oribasius in his thirteenth chapter *De Facultate Metallicorum*, Aetius Amidenus, Avicenna, Serapio Mauritanus, Hali Abbas, Santes de Ardoynis, Petrus Apponensis, Marcellus[9], Arnaldus. Bare mention is made of certain points relating to the loadstone in very few words by Marbodeus Callus, Albertus, Matthæus Silvaticus, Hermolaus Barbarus, Camillus Leonhardus, Cornelius Agrippa, Fallopius, {3} Johannes Langius, Cardinal Cusan, Hannibal Rosetius Calaber; by all of whom the subject is treated very negligently, while they merely repeat other people's fictions and ravings. Matthiolus compares the alluring powers of the loadstone which pass through iron materials, with the mischief of the torpedo, whose venom passes through bodies and spreads imperceptibly; Guilielmus Pateanus in his *Ratio Purgantium Medicamentorum* discusses the loadstone briefly and learnedly. Thomas Erastus[10], knowing little of magnetical nature, finds in the loadstone weak arguments against Paracelsus; Georgius Agricola, like Encelius[11] and other metallurgists, merely states the facts; Alexander Aphrodiseus in his *Problemata* considers the question of the loadstone inexplicable; Lucretius Carus, the poet of the Epicurean school, considers that an attraction is brought about in this way: that as from all things there is an efflux of very minute bodies, so from the iron atoms flow into the space emptied by the elements of the loadstone, between the iron and the loadstone, and that as soon as they have begun to stream towards the loadstone, the iron follows, its corpuscles being entangled. To much the same effect Johannes Costæus adduces a passage from Plutarch; Thomas Aquinas[12], writing briefly on the loadstone in Chapter VII. of his *Physica*, touches not amiss on its nature, and with his divine and clear intellect would have published much more, had he been conversant with magnetick experiments. Plato thinks the virtue divine. But when three or four hundred years afterwards, the magnetick movement to North and South was discovered or again recognized by men, many learned men attempted, each according to the bent of his own mind, either by wonder and praise, or by some sort of reasonings, to throw light upon a virtue so notable, and so needful for the use of mankind. Of more modern authors a great number have striven to show what is the cause of this direction and movement to North and South, and to understand this great miracle of nature, and to disclose it to others: but they have lost both their oil and their pains; for, not being practised in the subjects of nature, and being misled by certain false physical systems, they adopted as theirs, from books only, without magnetical experiments, certain inferences based on vain opinions, and many things that are not, dreaming old wives' tales. Marsilius Ficinus ruminates over the ancient opinions, and in order to show the reason of the direction seeks the cause in the heavenly constellation of the Bear, supposing the virtue of the Bear to prevail in the stone and to be transferred to the iron. Paracelsus asserted that there are stars, endowed with the power of the loadstone, which attract to themselves iron. Levinus Lemnius describes and praises the compass[13], and infers its antiquity on certain grounds; he does not divulge the hidden miracle which he propounds. In the kingdom of Naples the Amalfians were the first (so it is said) to {4} construct the mariners' compass: and as Flavius Blondus says the Amalfians[14] boast, not without reason, that they were taught by a certain citizen, Johannes Goia, in the year thirteen hundred after the birth of Christ. That town is situated in the kingdom of Naples not far from Salerno, near the promontory of Minerva; and Charles V. bestowed that principality on Andrea

Doria, that great Admiral, on account of his signal naval services. Indeed it is plain that no invention of man's device has ever done more for mankind than the compass: some notwithstanding consider that it was discovered by others previously and used in navigation, judging from ancient writings and certain arguments and conjectures. The knowledge of the little mariners' compass seems to have been brought into Italy by Paolo, the Venetian[15], who learned the art of the compass in the Chinas about the year MCCLX.; yet I do not wish the Amalfians to be deprived of an honour so great as that of having first made the construction common in the Mediterranean Sea. Goropius[16] attributes the discovery to the Cimbri or Teutons, forsooth because the names of the thirty-two winds inscribed on the compass are pronounced in the German tongue by all ship-masters, whether they be French, British, or Spaniards; but the Italians describe them in their own vernacular. Some think that Solomon, king of Judæa, was acquaint with the use of the mariners' compass, and made it known to his ship-masters in the long voyages when they brought back such a power of gold from the West Indies: whence also, from the Hebrew word *Parvaim*[17], Arias Montanus maintains that the gold-abounding regions of Peru are named But it is more likely to have come from the coast of lower Æthiopia, from the region of Cephala, as others relate. Yet that account seems to be less true, inasmuch as the Phœnicians, on the frontier of Judæa, who were most skilled in navigation in former ages (a people whose talents, work, and counsel Solomon made use of in constructing ships and in the actual expeditions, as well as in other operations), were ignorant of magnetick aid, the art of the mariners' compass: For had it been in use amongst them, without doubt the Greeks and also Italians and all barbarians would have understood a thing so necessary and made famous by common use; nor could matters of much repute, very easily known, and so highly requisite ever have perished in oblivion; but either the learning would have been handed down to posterity, or some memorial of it would be extant in writing. Sebastian Cabot was the first to discover that the magnetick iron varied[18]. Gonzalus Oviedus[19] is the first to write, as he does in the *Historia*, that in the south of the Azores it does not vary. Fernelius in his book *De Abditis Rerum Causis* says that in the loadstone there is a hidden and abstruse cause, elsewhere calling it celestial; and he brings forth nothing but the unknown by means of what is still more unknown. For clumsy, {5}
and meagre, and pointless is his inquiry into hidden causes. The ingenious Fracastorio, a distinguished philosopher, in seeking the reason for the direction of the loadstone, feigns Hyperborean magnetick mountains attracting magnetical things of iron: this view, which has found acceptance in part by others, is followed by many authors and finds a place not in their writings only, but in geographical tables, marine charts, and maps of the globe: dreaming, as they do, of magnetick poles and huge rocks, different from the poles of the earth. More than two hundred years earlier than Fracastorio there exists a little work, fairly learned for the time, going under the name of one Peter Peregrinus[20], which some consider to have originated from the views of Roger Bacon, the Englishman of Oxford: In which book causes for magnetick direction are sought from the poles of the heaven and from the heaven itself. From this Peter Peregrinus, Johannes Taisnier of Hainault[21] extracted materials for a little book, and published it as new. Cardan talks much of the rising of the star in the tail of the Greater Bear, and has attributed to its rising the cause of the variation: supposing that the variation is always the same, from the rising of the star. But the difference of the variation according to the change of position, and the changes which occur in many places, and are even irregular in southern regions, preclude the influence of one particular star at its northern rising. The College of Coimbra[22] seeks the cause in some part of the heaven near the pole: Scaliger in section CXXXI. of his *Exercitationes* on Cardan suggests a heavenly cause unknown to himself, and terrestrial loadstones nowhere yet discovered. A cause not due to those sideritic mountains named above, but to that power which fashioned them, namely that portion of the heaven which overhangs that northern point. This view is garnished with a wealth of words by that erudite man, and crowned with many marginal subtilities; but with reasonings not so subtile. Martin Cortes[23] considers that there is a place of attraction beyond the poles, which he judges to be the moving heavens. One Bessardus[24], a Frenchman, with no less folly notes the pole of the zodiack. Jacobus Severtius[25], of Paris, while quoting a few points, fashions new errors as to loadstones of different parts of the earth being different in direction: and also as to there being eastern and western parts of the loadstone. Robert Norman[26], an Englishman, fixes a point and region respective, not attractive; to which the magnetical iron is collimated, but is not itself attracted. Franciscus Maurolycus[27] treats of a few problems on the loadstone, taking the trite views of others, and avers that the variation is due to a certain magnetical island mentioned by Olaus Magnus[28]. Josephus Acosta[29], though quite ignorant about the loadstone, nevertheless pours forth vapid talk upon the loadstone. Livio Sanuto[30] in his Italian *Geographia*, discusses at length the question whether the prime magnetick meridian and the magnetick poles are in the heavens or in the earth; also about an {6}
instrument for finding the longitude: but through not understanding magnetical nature, he raises nothing but errors and mists in that so important notion. Fortunius Affaytatus[31] philosophizes foolishly enough on the attraction of iron, and its turning to the poles. Most recently, Baptista Porta[32], no ordinary philosopher, in his *Magia Naturalis*, has made the seventh book a custodian and distributor of the marvels of the loadstone; but little did he know or ever see of magnetick motions; and some things that he noted of the powers which it manifested, either learned by him from the Reverend Maestro Paolo, the Venetian[33], or evolved from his own vigils, were not so well discovered or observed; but abound in utterly false experiments, as will be clear in due place: still I deem him worthy of high praise for having attempted so great a subject (as he has done with sufficient success and no mean result in many other instances), and for having given

occasion for further research. All these philosophizers of a previous age, philosophizing about attraction from a few vague and untrustworthy experiments, drawing their arguments from the hidden causes of things; and then, seeking for the causes of magnetick directions in a quarter of the heavens, in the poles, the stars, constellations, or in mountains, or rocks, space, atoms, attractive or respective points beyond the heavens, and other such unproven paradoxes, are whole horizons wrong, and wander about blindly. And as yet we have not set ourselves to overthrow by argument those errors and impotent reasonings of theirs, nor many other fables told about the loadstone, nor the superstitions of impostors and fabulists: for instance, Franciscus Rueus'[34] doubt whether the loadstone were not an imposture of evil spirits: or that, placed underneath the head of an unconscious woman while asleep, it drives her away from the bed if an adulteress: or that the loadstone is of use to thieves by its fume and sheen, being a stone born, as it were, to aid theft: or that it opens bars and locks, as Serapio[35] crazily writes: or that iron held up by a loadstone, when placed in the scales, added nothing to the weight of the loadstone, as though the gravity of the iron were absorbed by the force of the stone: or that, as Serapio and the Moors relate, in India there exist certain rocks of the sea abounding in loadstone, which draw out all the nails of the ships which are driven toward them, and so stop their sailing; which fable Olaus Magnus[36] does not omit, saying that there are mountains in the north of such great powers of attraction, that ships are built with wooden pegs, lest the iron nails should be drawn from the timber as they passed by amongst the magnetick crags. Nor this: that a white loadstone may be procured as a love potion: or as Hali Abbas[37] thoughtlessly reports, that if held in the hand it will cure gout and spasms: Or that it makes one acceptable and in favour with princes, or eloquent, as Pictorio[38] has sung; Or as Albertus Magnus[39] teaches, that there are two kinds of {7}
loadstones, one which points to the North, the other to the South: Or that iron is directed toward the Northern stars by an influence imparted by the polar stars, even as plants follow the sun, as Heliotrope does: Or that there is a magnet-stone situated under the tail of the Greater Bear, as Lucas Gauricus the Astrologer stated: He would even assign the loadstone, like the Sardonyx and onyx, to the planet Saturn, yet at the same time he assigns it with the adamant, Jasper, and Ruby, to Mars; so that it is ruled by two planets. The loadstone moreover is said by him to pertain to the sign Virgo; and he covers many such shameful pieces of folly with a veil of mathematical erudition. Such as that an image of a bear is engraved on a loadstone when the Moon faces towards the north, so that when hung by an iron wire it may conciliate the influence of the celestial Bear, as Gaudentius Merula[40] relates: Or that the loadstone drew iron and directed it to the north, because it is superior in rank to iron, at the Bear, as Ficinus writes, and Merula repeats: Or that by day it has a certain power of attracting iron, but by night the power is feeble, or rather null: Or that when weak and dulled the virtue is renewed by goats' blood, as Ruellius[41] writes: Or that Goats' blood sets a loadstone free from the venom of a diamond, so that the lost power is revived when bathed in goats' blood by reason of the discord between that blood and the diamond: Or that it removed sorcery from women, and put to flight demons, as Arnaldus de Villanova dreams: Or that it has the power to reconcile husbands to their wives, or to recall brides to their husbands, as Marbodeus Gallus[42], chorus-leader of vanities, teaches: Or that in a loadstone pickled in the salt of a sucking fish[43] there is power to pick up gold which has fallen into the deepest wells, according to the narratives of Cælius Calcagninus. With such idle tales and trumpery do plebeian philosophers delight themselves and satiate readers greedy for hidden things, and unlearned devourers of absurdities: But after the magnetick nature shall have been disclosed by the discourse that is to follow, and perfected by our labours and experiments, then will the hidden and abstruse causes of so great an effect stand out, sure, proven, displayed and demonstrated; and at the same time all darkness will disappear, and all error will be torn up by the roots and will lie unheeded; and the foundations of a grand magnetick philosophy which have been laid will appear anew, so that high intellects may be no further mocked by idle opinions. Some learned men there are who in the course of long voyages have observed the differences of magnetick variation: the most scholarly Thomas Hariot[44], Robert Hues, Edward Wright, Abraham Kendall, all Englishmen; Others there are who have invented and produced magnetical instruments, and ready methods of observation, indispensable for sailors and to those travelling afar: as William Borough[45] in his little book on the *Variation of the Compass* or Magneticall {8}
Needle, William Barlowe[46] in his *Supply*, Robert Norman in his *Newe Attractive*. And this is that Robert Norman[47] (a skilful seaman and ingenious artificer) who first discovered the declination of the magnetick needle. Many others I omit wittingly; modern Frenchmen, Germans, and Spaniards, who in books written for the most part in their native tongues either misuse the placets of others, and send them forth furbished with new titles and phrases as tricky traders do old wares with meretricious ornaments; or offer something not worthy of mention even: and these lay hands on some work filched from other authors and solicit some one as their patron, or go hunting after renown for themselves among the inexperienced and the young; who in all branches of learning are seen to hand on errors and occasionally add something false of their own.

CHAP. II.

Magnet Stone, of what kind it is, and its *discovery.*

 oadstone, the stone which is commonly called the Magnet, derives its name either from the discoverer (though he was not Pliny's fabulous herdsman[48], quoted from Nicander, the nails of whose shoes and the tip of whose staff stuck fast in a magnetick field while he pastured his flocks), or from the region of Magnesia in Macedonia, rich in loadstones: Or else from the city Magnesia in Ionia in Afia Minor, near the river Mæander. Hence Lucretius says,

> *The Magnet's name the observing Grecians drew*
> *From the Magnetick region where it grew.*

It is called Heraclean from the city Heraclea, or from the invincible Hercules, on account of the great strength and domination and power which there is in iron of subduing all things: it is also called *siderite*, as being of iron; being not unknown to the most ancient writers, to the Greeks, Hippocrates, and others, as also (I believe) to Jewish and Egyptian writers; For in the oldest mines of iron, the most famous in Asia, the loadstone was often dug out with its uterine brother, iron. And if the tales be true which are told of the people of the Chinas, they were not unacquainted in primitive times with magnetical experiments, for even amongst them the finest {9} magnets of all are still found. The Egyptians, as Manetho relates, gave it the name Os Ori: calling the power which governs the turning of the sun Orus, as the Greeks call it Apollo. But later by Euripides, as narrated by Plato, it was designated under the name of Magnet. By Plato in the *Io*, Nicander of Colophon, Theophrastus, Dioscorides, Pliny, Solinus, Ptolemy, Galen, and other investigators of nature it was recognized and commended; such, however, is the variety of magnets and their points of unlikeness in hardness, softness, heaviness, lightness, density, firmness, and friability of substance: so great and manifold are the differences in colour and other qualities, that they have not handed down any adequate account of it, which therefore was laid aside or left imperfect by reason of the unfavourable character of the time; for in those times varieties of specimens and foreign products never before seen were not brought from such distant regions by traders and mariners as they have been lately, and now that all over the globe all kinds of merchandise, stones, woods, spices, herbs, metals, and ore in abundance are greedily sought after: neither was metallurgy so generally cultivated in a former age. There is a difference in vigour; as whether it is male or female: for it was thus that the ancients used often to distinguish many individuals of the same species. Pliny quotes from Sotacus five kinds; those from Æthiopia, Macedonia, Bœotia, the Troad, and Asia, which were especially known to the ancients: but we have posited as many kinds of loadstones as there are in the whole of nature regions of different kinds of soil. For in all climates, in every province, on every soil, the loadstone is either found, or else lies unknown on account of its rather deep site and inaccesible position; or by reason of its weaker and less obvious strength it is not recognized by us while we see and handle it. To the ancients the differences were those of colour[49], how they are red and black in Magnesia and Macedonia, in Bœotia red rather than black, in the Troad black, without strength: While in Magnesia in Asia they are white, not attracting iron, and resemble pumice-stone. A strong loadstone of the kind celebrated so often nowadays in experiments presents the appearance of unpolished iron, and is mostly found in iron mines: it is even wont to be discovered in an unbroken lode by itself: Loadstones of this sort are brought from East India, China, and Bengal, of the colour of iron, or of a dark blood or liver colour; and these are the finest, and are sometimes of great size, as though broken off a great rock, and of considerable weight; sometimes single stones, as it were, and entire: some of these, though of only one pound weight, can lift on high four ounces of iron or a half-pound or even a whole pound. Red ones are found in Arabia, as broad as a tile, not equal in weight to those brought from China, but strong and good: they are a little darker in the island of Elba in the Tuscan sea, and together with these also grow {10} white ones, like some in Spain in the mines of Caravaca: but these are of lesser power. Black ones also are found, of lower strength, such as those of the iron mines in Norway and in sea-coast places near the strait of Denmark. Amongst the blue-black or dusky blue also some are strong and highly commended. Other loadstones are of a leaden colour, fissile and not-fissile, capable of being split like slates in layers. I have also some like gray marble of an ashen colour, and some speckled like gray marble, and these take the finest polish. In Germany there are some perforated like honeycombs, lighter than any others, and yet strong. Those are metallick which smelt into the best iron; others are not easily smelted, but are burned up. There are loadstones that are very heavy, as also others very light; some are very powerful in catching up pieces of iron, while others are weaker and of less capacity, others so feeble and barren that they with difficulty attract ever so tiny a piece of iron and cannot repel an opposite magnetick. Others are firm and tough, and do not readily yield to the artificer. Others are friable. Again, there are some dense and hard as emery, or loose-textured and soft as pumice; porous or solid; entire and uniform, or varied and corroded; now like iron for hardness, yea, sometimes harder than iron to cut or to file; others are as soft as clay. Not all magnets can be properly called stones; some rather represent rocks; while others exist rather as metallick lodes; others as clods and lumps of earth. Thus varied and unlike each other, they are all endowed, some more, some less, with the peculiar virtue. For they vary according to the nature of the soil, the different admixture of clods and humours, having respect to the nature of the region and to their subsidence in this last-formed crust of the earth, resulting from the confluence of many causes, and the perpetual alternations of growth and decline, and the mutations of bodies. Nor is this stone of such potency rare; and there is no region wherein it is not to be found in some sort. But if men were to search for it more diligently and at greater outlay, or were able, where difficulties are present, to mine it, it would come to hand everywhere, as we shall hereafter prove. In many countries have been found and opened mines of efficacious loadstones unknown to the ancient writers, as for instance

in Germany, where none of them has ever asserted that loadstones were mined. Yet since the time when, within the memory of our fathers, metallurgy began to flourish there, loadstones strong and efficacious in power have been dug out in numerous places; as in the Black Forest beyond Helceburg; in Mount Misena not far from Schwartzenberg[50]; a fairly strong kind between Schneeberg and Annaberg in Joachimsthal, as was noticed by Cordus: also near the village of Pela in Franconia. In Bohemia it occurs in iron mines in the Lessa district and other places, as Georgious Agricola and several other men learned in metallurgy witness. In like {11} manner in other countries in our time it is brought to light; for as the stone remarkable for its virtues is now famous throughout the whole world, so also everywhere every land produces it, and it is, so to speak, indigenous in all lands. In East India, in China, in Bengal near the river Indus it is common, and in certain maritime rocks: in Persia, Arabia, and the islands of the Red Sea; in many places in Æthiopia, as was formerly Zimiri, of which Pliny makes mention. In Asia Minor around Alexandria and the Troad; in Macedonia, Bœotia, in Italy, the island of Elba, Barbary; in Spain still in many mines as aforetime. In England quite lately a huge power of it was discovered in a mine belonging to Adrian Gilbert, gentleman[51]; also in Devonshire and the Forest of Dean; in Ireland, too, Norway, Denmark, Sweden, Lapland, Livonia, Prussia, Poland, Hungary. For although the terrestrial globe, owing to the varied humours and natures of the soil arising from the continual succession of growth and decay, is in the lapse of time efflorescing through all its ambit deeper into its surface, and is girt about with a varied and perishable covering, as it were with a veil; yet out of her womb ariseth in many places an offspring nigher to the more perfect body and makes its way to the light of day. But the weak and less vigorous loadstones, enfeebled by the flow of humours, are visible in every region, in every strath. It is easy to discover a vast quantity of them everywhere without penetrating mountains or great depths, or encountering the difficulties and hardships of miners; as we shall prove in the sequel. And these we shall take pains so to prepare by an easy operation that their languid and dormant virtue shall be made manifest. It is called by the Greeks[52] ἑράκλιος, as by Theophrastus, and μαγνῆτις; and μάγνης, as by Euripides, as quoted by Plato in the *Io*: by Orpheus[53] too μαγνῆοσα, and σιδερίτης as though of iron: by the Latins *magnes*, *Herculeus*; by the French *aimant*[54], corruptly from *adamant*; by the Spaniards *piedramant*: by the Italians *calamita*[55]; by the English **loadstone** and **adamant stone**[56], by the Germans *magness*[57] and *siegelstein*: Among English, French, and Spaniards it has its common name from adamant; perhaps because they were at one time misled by the name *sideritis* being common to both: the magnet is called σιδερίτης from its virtue of attracting iron: the adamant is called σιδερίτης from the brilliancy of polished iron. Aristotle designates it merely by the name of *the stone*:[58] Ἔοικε δὲ καὶ θαλῆς ἐξ ὧν ἀπομνημονεύουσι, κινητικόν τι τὴν ψυχὴν ὑπολαβεῖν, ἔιπερ τὸν λίθον ἔφη ψυχὴν ἔχειν, ὅτι τὸν σίδηρον κινεῖ: *De Anima*, Lib. I. The name of magnet is also applied to another stone differing from siderite, having the appearance of silver; it is like Amianth in its nature; and since it consists of laminæ (like specular stone)[59], it differs in form: in German *Katzensilber* and *Talke*[60].

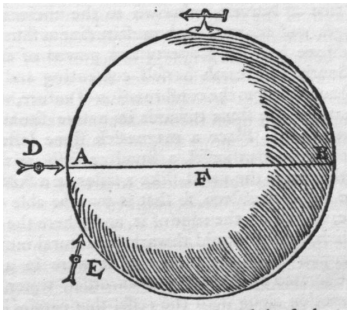
{12}

CHAP. III.

The Loadstone has parts distinct in their natural *power, & poles conspicuous for their property.*

he stone itself manifests many qualities which, though known afore this, yet, not having been well investigated, are to be briefly indicated in the first place so that students may understand the powers of loadstone and iron, and not be troubled at the outset through ignorance of reasonings and proofs. In the heaven astronomers assign a pair of poles for each moving sphere: so also do we find in the terrestrial globe natural poles preeminent in virtue, being the points that remain constant in their position in respect to the diurnal rotation, one tending to the Bears and the seven stars; the other to the opposite quarter of the heaven. In like manner the loadstone has its poles, by nature northern and southern, being definite and determined points set in the stone, the primary boundaries of motions and effects, the limits and governors of the many actions and virtues. However, it must be understood that the strength of the stone does not emanate from a mathematical point, but from the parts themselves, and that while all those parts in the whole belong to the whole, the nearer they are to the poles of the stone the stronger are the forces they acquire and shed into other bodies: these poles are observant of the earth's poles, move toward them, and wait upon them. Magnetick poles can be found in every magnet, in the powerful and mighty (which Antiquity used to call the masculine) as well as in the weak, feeble and feminine; whether its figure is due to art or to chance, whether long, flat, square, three-cornered, polished; whether
* rough, broken, or unpolished; always the loadstone contains and shows its poles. But since the spherical form, which is also the most perfect, agrees best with the earth, being a globe, and is most suitable for use and experiment, we accordingly wish our principal demonstrations by the stone to be made with a globe-shaped magnet as being more perfect and adapted for the purpose. Take, then, a powerful loadstone, solid, of a just size, uniform, hard, without flaw[61]; make of it a globe upon the turning tool used for rounding crystals and some other stones, or with other tools as the material and firmness of the stone requires, for sometimes it is difficult to

be worked. The stone thus perpared is a true, homogeneous offspring of the earth and of the same shape with it: artificially possessed of the orbicular form which nature granted from the beginning to the common mother earth: and it is a physical corpuscle imbued with many virtues, by means of which many abstruse and neglected truths in philosophy buried in piteous darkness {13} may more readily become known to men. This round stone is called by us a μικρόγη or *Terrella*[62]. To find, then, the poles conformable to the earth's, take the round stone in hand, and place upon the stone a needle or wire of iron: the ends of the iron move upon their own centre and suddenly stand still. Mark the stone with ochre or with chalk where the wire lies and sticks: move the middle or centre of the wire to another place, and so on to a third and a fourth, always marking on the stone along the length of the iron where it remains at rest: those lines show the meridian circles, or the circles like meridians on the stone, or terrella, all of which meet as will be manifest at the poles of the stone. By the circles thus continued the poles are made out, the Boreal as well as the southern, and in the middle space betwixt these a great circle may be drawn for an æquator, just as Astronomers describe them in the heavens and on their own globes, or as Geographers do on the terrestrial globe: for that line so drawn on this our terrella is of various uses in our demonstrations and experiments magnetical. Poles are also found in a round stone by a versorium, a piece of iron touched with a loadstone, and placed upon a needle or point firmly fixed on a foot so as to turn freely about in the following way:[63]



On the stone A B the versorium is placed in such a way that the versorium may remain in equilibrium: you will mark with chalk the course of the iron when at rest: Move the instrument to another spot, and again make note of the direction and aspect: do the same thing in several places, and from the concurrence of the lines of direction you will find one pole at the point A, the other at B. A versorium placed near the stone also indicates the true pole; when at right angles it eagerly beholds the stone and seeks the pole itself directly, and is turned in a straight line through the axis to the centre of the stone. For instance, the versorium D faces toward A and F, {14}
* the pole and centre, whereas E does not exactly respect either the pole A or the centre F[64]. A bit of rather fine iron wire, of the length of a barley-corn, is placed on the stone, and is moved over the regions and surface of the stone, until it rises to the perpendicular[65]: for it stands erect at the actual pole, whether Boreal or austral; the further from the pole, the more it inclines from the vertical. The poles thus found you shall mark with a sharp file or gimlet.

CHAP. IIII.

Which pole of the stone is the Boreal: & how it is *distinguished from the austral.*

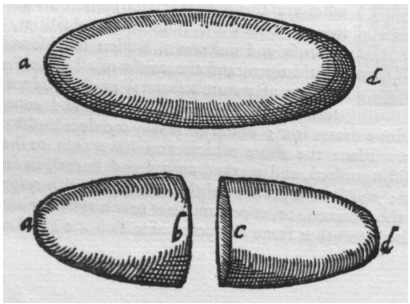
One pole of the earth turns toward the constellation of the Cynosure, and constantly regards a fixed point in the heaven (except so far as it changes by the fixed stars being shifted in longitude, which motion we recognize as existing in the earth, as we shall hereafter prove): While the other pole turns to the opposite face of heaven, unknown to the ancients, now visible on long voyages, and adorned with multitudinous stars: In the same way the loadstone has the property and power of directing itself North and South (the earth herself consenting and contributing force thereto) according to the conformation of nature, which arranges the movements of the stone towards its native situation. Which thing is proved thus: Place a magnetick stone (after finding the poles) in a round wooden vessel, a Bowl or dish, at the same time place it together with the vessel (like a sailor in a skiff) upon water in some large vessel or cistern, so that it may be able to float freely in the middle, nor touch the edge of it, and where the air is not disturbed by winds, which would thwart the natural movement of the stone. Hereupon the stone placed as it were in a ship, in the middle of the surface of the still and unruffled water, will at once put itself in motion along with the vessel that carries it, and revolve circularly, until its austral pole points to the north, and its boreal pole to the south. For it reverts from the contrary position to the poles: and although by the first too-vehement impulse it over-passes the poles; yet after returning again and again, it rests at length at the poles, or at the meridian (unless because of local reasons it is diverted some little from those points, or from the meridional line, by some sort of variation[66], the cause of which we will hereafter state). However often you move it away from its place, so often by virtue of nature's noble dower does it seek again those sure and determined goals; and this is so, not only if the poles have been {15}

disposed in the vessel evenly with the plane of the horizon, but also in the case of one pole, whether austral or boreal, being raised in the vessel ten, or twenty, or thirty, or fifty or eighty
* degrees, above the plane of the horizon, or lowered beneath it: Still you shall see the boreal part of the stone seek the south, and the austral part seek the north; So much so that if the pole of the stone shall be only one degree distant from the Zenith and highest point of the heaven, in the case of a spherical stone, the whole stone revolves until the pole occupies its own site; though not in the absolutely direct line, it will yet tend toward those parts, and come to rest in the meridian of the directive action. With a like impulse too it is borne if the austral pole have been raised toward the upper quarters, the same as if the Boreal had been exalted above the Horizon. But it is always to be noted that, though there are various kinds of unlikeness in the stones, and one loadstone may far surpass another in virtue and efficiency; yet all hold to the same limits, and are
* borne toward the same points. Further it is to be remembered that all who before our time wrote of the poles of the stone, and all the craftsmen and navigators, have been very greatly in error in considering the part of the stone which tended to the north as the north pole of the stone, and that which verged toward the south, the south pole, which we shall hereafter prove to be false. So badly hitherto hath the whole magnetick philosophy been cultivated, even as to its foundation principles.

CHAP. V.

Loadstone seems to attract Loadstone when in natural position: but repels it when in a contrary one, and brings *it back to order*.

irst of all we must declare, in familiar language, what are the apparent and common virtues of the stone; afterward numerous subtilities, hitherto abstruse and unknown, hidden in obscurity, are to be laid open, and the causes of all these (by the unlocking of nature's secrets) made evident, in their place, by fitting terms and devices. It is trite and commonplace that loadstone draws iron; in the same way too does loadstone attract loadstone. Place the stone which you have seen to have poles clearly distinguished, and marked austral and boreal, in its vessel so as to float; and let the poles be rightly arranged with respect to the plane of the horizon, or, at any rate not much raised or awry: hold in your hand another stone the poles of which are also known; in such a way that its austral {16}
pole may be toward the boreal pole of the one that is swimming, and near it, sideways: for the floating stone forthwith follows the other stone (provided it be within its force and dominion) and does not leave off nor forsake it until it adhæres; unless by withdrawing your hand, you cautiously avoid contact. In like manner if you set the boreal pole of the one you hold in your hand opposite the austral pole of the swimming stone, they rush together and follow each other in turn. For contrary poles allure contrary. If, however, you apply in the same way the northern to the northern, and the austral to the austral pole, the one stone puts the other to flight, and it turns aside as though a pilot were pulling at the helm and it makes sail in the opposite ward as one that ploughs the sea, and neither stands anywhere, nor halts, if the other is in pursuit. For stone disposeth stone; the one turns the other around, reduces it to range, and brings it back to harmony with itself. When, however, they come together and are conjoined according to the order of nature, they cohære firmly mutually. For instance, if you were to set the boreal pole of that stone which is in your hand before the tropic of Capricorn of a round floating loadstone (for it will be well to mark out on the round stone, that is the terrella, the mathematical circles as we do on a globe itself), or before any point between the æquator and the austral pole; at once the swimming stone revolves, and so arranges itself that its austral pole touches the other's boreal pole, and forms a close union with it. In the same way, again, at the other side of the æquator, with the opposite poles, you may produce similar results; and thus by this art and subtilty we exhibit attraction, repulsion, and circular motion for attaining a position of agreement and for declining hostile encounters. Moreover 'tis in one and the same stone that we are thus able to demonstrate all these things and also how the same part of one stone may on division become either boreal or austral. Let A D be an oblong stone, in which A is the northern, D the southern pole; cut this into two equal parts, then set part A in its vessel on the water[67], so as to float.



And you will then see[68] that A the northern point will turn to the south, as before; in like {17}
manner also the point D will move to the north, in the divided stone, as in the whole one.

Whereas, of the parts B and C, which were before continuous, and are now divided, the one is southern B, the other northern C. B draws C, desirous to be united, and to be brought back into its pristine continuity: for these which are now two stones were formed out of one: and for this cause C of the one turning itself to B of the other, they mutually attract each other, and when freed from obstacles and relieved of their own weight, as upon the surface of water, they run together and are conjoined. But if you direct the part or point A to C in the other stone, the one repels or turns away from the other: for so were nature perverted, and the form of the stone perturbed, a form that strictly keeps the laws which it imposed upon bodies: hence, when all is not rightly ordered according to nature, comes the flight of one from the other's perverse position and from the discord, for nature does not allow of an unjust and inequitable peace, or compromise: but wages war and exerts force to make bodies acquiesce well and justly. Rightly arranged, therefore, these mutually attract each other; that is, both stones, the stronger as well as the weaker, run together, and with their whole forces tend to unity, a fact that is evident in all magnets, not in the Æthiopian only, as Pliny supposed. The Æthiopian magnets if they be powerful, like those brought from China, because all strong ones show the effect more quickly and more plainly, attract more strongly in the parts nearest the pole, and turn about until pole looks directly at pole. The pole of a stone more persistently attracts and more rapidly seizes the corresponding part (which they term the adverse part) of another stone; for instance, North pulls South; just so it also summons iron with more vehemence, and the iron cleaves to it more firmly whether it have been previously excited by the magnet, or is untouched. For thus, not without reason hath it been ordained by nature, that the parts nearer to the pole should more firmly attract: but that at the pole itself should be the seat, the throne, as it were, of a consummate and splendid virtue, to which magnetical bodies on being brought are more vehemently attracted, and from which they are with utmost difficulty dislodged. So the poles are the parts which more particularly spurn and thrust away things strange and alien perversely set beside them.

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CHAP. VI.

Loadstone attracts the ore of iron, as well as iron *proper, smelted and wrought.*

* Principal and manifest among the virtues of the magnet, so much and so anciently commended, is the attraction of iron; for Plato states that the magnet, so named by Euripides, allures iron, and that it not only draws iron rings but also indues the rings with power to do the same as the stone; to wit, draw other rings, so that sometimes a long chain of iron objects, nails or rings is formed, some hanging from others. The best iron (like that which is called *acies* from its use, or *chalybs* from the country of the Chalybes) is best and strongly drawn by a powerful loadstone; whereas the less good sort, which is impure, rusty, and not thoroughly purged from dross, and not wrought in second furnaces, is more feebly drawn; and yet more weakly when covered and defiled with thick, greasy, and sluggish humours. It also draws ores of iron, those that are rich and of iron colour; the poorer and not so productive ores it does not attract, except they be prepared with some art. A loadstone loses some attractive virtue, and, as it were, pines away with age, if exposed too long to the open air instead of being laid in a case with filings or scales of iron. Whence it should be buried in such materials; for there is nothing that plainly resists this exhaustless virtue which does not destroy the form of the body, or corrode it; not even if a thousand adamants were conjoined. Nor do I consider that there is any such thing as the Theamedes[69], or that it has a power opposite to that of the loadstone. Although Pliny, that eminent man and prince of compilers (for it is what others had seen and discovered, not always or mainly his own observations, that he has handed down to posterity) has copied from others the fable now made familiar by repetition: That in India there are two mountains near the river Indus; the nature of one being to hold fast all that is iron, for it consists of loadstone; the other's nature being to repel it, for it consists of the Theamedes. Thus if one had iron nails in one's boots, one could not tear away one's foot on the one mountain, nor stand still on the other. Albertus Magnus writes that a loadstone had been found in his day which with one part drew to itself iron, and repelled it with its other end; but Albertus observed the facts badly; for every loadstone attracts with one end iron that has been touched with a loadstone, and drives it away with the other; and draws iron that been touched with a loadstone more powerfully than iron that has not been so touched.

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CHAP. VII.

What Iron is, and of what substance, *and its uses.*

For that now we have declared the origin and nature of the loadstone, we think it necessary first to add a history of iron and to indicate the hitherto unknown forces of iron, before this our discourse goes on to the explanation of magnetick difficulties and demonstrations, and to deal with the coitions and harmonies of loadstone with iron. Iron is by all reckoned in the class of metals, and is a metal livid in colour, very hard, glows red-hot before it melts, being most difficult of fusion, is beaten out under the hammer, and is very resonant. Chemists say that if a bed of fixed earthy sulphur be combined with fixed earthy quicksilver, and the two together are neither pure white but of a livid whiteness, if the sulphur prevail, iron is formed. For these stern masters of metals who by many inventions twisting them about, pound, calcine, dissolve, sublime, and precipitate, decide that this metal, both on account of the earthy sulphur and of the earthy mercury, is more truly a son of the earth than any other; they do not even think gold or silver, lead, tin, or copper itself so earthy; for that reason it is not smelted except in the hottest furnaces, with bellows; and when thus fused, on having again grown hard it is not melted again without heavy labour; but its slag with the utmost difficulty. It is the hardest of metals, subduing and breaking all things, by reason of the strong concretion of the more earthy matter. Wherefore we shall better understand what iron is, when we shall declare what are the causes and substance of metals, in a different way from those who before our time have considered them. Aristotle takes the material of the metals to be vapour. The chemists in chorus pronounce their actual elements to be sulphur and quicksilver. Gilgil Mauritanus gives it as ashes moistened with water. Georgius Agricola makes it out to be water and earth mixed; nor, to be sure, is there any difference between his opinion and the position taken by Mauritanus. But ours is that metals arise and effloresce at the summits of the earth's globe, being distinguished each by its own form, like some of the other substances dug out of it, and all bodies around us. The earth's globe does not consist of ashes or inert dust. Nor is fresh water an element, but a more simple consistency of evaporated fluids of the earth. Unctuous bodies, fresh water devoid of properties, quicksilver and sulphur, none of these are principia of metals: these latter, things are the results of a different nature, they are neither {20} constant nor antecedent in the course of the generation of metals. The earth emits various humours, not begotten of water nor of dry earth, nor from mixtures of these, but from the substance of the earth itself: these humours are not distinguished by contrary qualities or substance, nor is the earth a simple substance, as the Peripateticks dream. The humours proceed from vapours sublimated from great depths; all waters are extracts and, as it were, exudations from the earth. Rightly then in some measure does Aristotle make out the matter of metals to be that exhalation which in continuance thickens in the lodes of certain soils: for the vapours are condensed in places which are less hot than the spot whence they issued, and by help of the nature of the soils and mountains, as in a womb, they are at fitting seasons congealed and changed into metals: but it is not they alone which form ores, but they flow into and enter a more solid material, and so form metals. So when this concreted matter has settled down in more temperate beds, it begins to take shape in those tepid places, just as seed in the warm womb, or as the embryo acquires growth: sometimes the vapour conjoins with suitable matter alone: hence some metals are occasionally though rarely dug up native, and come into existence perfect without smelting: but other vapours which are mixed with alien soils require smelting in the way that the ores of all metals are treated, which are rid of all their dross by the force of fires, and being fused flow out metallick, and are separated from earthy impurities but not from the true substance of the earth. But in so far as that it becomes gold, or silver, or copper, or any other of the existing metals, this does not happen from the quantity or proportion of material, nor from any forces of matter, as the Chemists fondly imagine; but when the beds and region concur fitly with the material, the metals assume forms from the universal nature by which they are perfected; in the same manner as all the other minerals, plants, and animals whatever: otherwise the species of metals would be vague and undefined, which are even now turned up in such scanty numbers that scarce ten kinds are known. Why, however, nature has been so stingy as regards the number of metals, or why there should be as many as are known to man, it is not easy to explain; though the simple-minded and raving Astrologers refer the metals each to its own planet. But there is no agreement of the metals with the planets, nor of the planets with the metals, either in numbers or in properties. For what connexion is there of iron with Mars? unless it be that from the former numerous instruments, particularly swords and engines of war, are fashioned. What has copper to do with Venus? or how does tin, or how does spelter correspond with Jupiter? They should rather be dedicated to Venus. But this is old wives' talk. Vapour is then a remote cause in the generation of the metals; the fluid condensed from vapours is a more {21} proximate one, like the blood and semen in the generation of animals. But those vapours and juices from vapours pass for the most part into bodies and change them into marcasites and are carried into lodes (for we have numerous cases of wood so transmuted), the fitting matrices of bodies, where they are formed as metals. They enter most often into the truer and more homogeneal substance of the globe, and in the process of time a vein of iron results; loadstone is also produced, which is nought else than a noble kind of iron ore: and for this reason, and on account of its substance being singular, alien from all other metals, nature very rarely, if ever, mixes with iron any other metal, while the other metals are very often minutely mixed, and are produced together. Now when that vapour or those juices happen to meet, in fitting matrices, with efflorescences deformed from the earth's homogenic substance, and with divers precipitates (the forms working thereto), the remainder of the metals are generated (a specifick nature affecting the properties in that place). For the hidden primordial elements of metals and stones lie concealed in the earth, as those of herbs and plants do in its outer crust. For the soil dug out of a deep well, where would seem to be no suspicion of a conception of seed, when placed on a very high tower, produces, by the incubation of sun and sky, green herbage and unbidden weeds; and those of the kind which grow spontaneously in that region, for each region produces its own

herbs and plants, also its own metals.

> [70]*Here corn exults, and there the grape is glad,*
> *Here trees and grass unbidden verdure add.*
> *So mark how Tmolus yields his saffrone store,*
> *But ivory is the gift of Indian shore;*
> *With incense soft the softer Shebans deal;*
> *The stark Chalybeans' element is steel:*
> *With acrid castor reek the Pontic wares,*
> *Epirus wins the palm of Elian mares.*

But what the Chemists (as Geber, and others) call fixed earthy sulphur in iron is nothing else than the homogenic earth-substance concreted by its own humour, amalgamated with a double fluid: a metallick humour is inserted along with a small quantity of the substance of the earth not devoid of humour. Wherefore the common saying that in gold there is pure earth, but in iron mostly impure, is wrong; as though there were indeed such a thing as natural earth, and that the globe itself were (by some unknown process of refining) depurate. In iron, especially in the best iron, there is earth in its own nature true and genuine; in the other metals there is not so much earth as that in place of earth and precipitates there are consolidated and (so to speak) fixed salts, which are efflorescences of the globe, and which differ also greatly in firmness and {22} consistency: In the mines their force rises up along with a twofold humour from the exhalations, they solidify in the underground spaces into metallic veins: so too they are also connate by virtue of their place and of the surrounding bodies, in natural matrices, and take on their specific forms. Of the various constitutions of loadstones and their diverse substances, colours, and virtues, mention has been made before: but, now having stated the cause and origin of metals, we have to examine ferruginous matter not as it is in the smelted metal, but as that from which the metal is refined. Quasi-pure iron is found of its proper colour and in its own lodes; still, not as it will presently be, nor as adapted for its various uses. It is sometimes dug up covered with white silex or with other stones. It is often the same in river sand, as in Noricum. A nearly pure ore of iron is now often dug up in Ireland, which the smiths, without the labours of furnaces, hammer out in the smithy into iron implements. In France iron is very commonly smelted out of a liver-coloured stone, in which are glittering scales; the same kind[71] without the scales is found in England, which also they use for craftsmen's ruddle[72]. In Sussex in England[73] is a rich dusky ore and also one of a pale ashen hue, both of which on being dried for a time, or kept in moderate fires, presently acquire a liver-colour; here also is found a dusky ore square-shaped with a black rind of greater hardness. An ore having the appearance of liver is often variously intermingled with other stones: as also with the perfect loadstone which yields the best of iron. There is also a rusty ore of iron, one of a leaden hue tending to black, one quite black, or black mixed with true cobalt: there is another sort mixed either with pyrites, or with sterile plumbago. One kind is also like jet, another like bloodstone. The emery used by armourers, and by glaziers for glass-cutting, called amongst the English Emerelstone, by the Germans Smeargel, is ferruginous; albeit iron is extracted from it with difficulty, yet it attracts the versorium. It is now and then found in deep iron and silver diggings. Thomas Erastus says he had heard from a certain learned man of iron ores, of the colour of iron, but quite soft and fatty, which can be smoothed with the fingers like butter, out of which excellent iron can be smelted: somewhat the same we have seen found in England, having the aspect of Spanish soap. Besides the numberless kinds of stony ores, iron is extracted from clay, from clayey earth, from ochre, from a rusty matter deposited from chalybeate waters; In England iron is copiously extracted in furnaces often from sandy and clayey stones which appear to contain iron not more than sand, marl, or any other clay soils contain it. Thus in Aristotle's book *De Mirabilibus Auscultationibus*[74], "There is said" (he states) "to be a peculiar formation of Chalybean and Misenian iron, for instance the sort collected from river gravel; some say that after being simply washed it is smelted in the furnace; others declare that it {23} and the sediment which subsides after several washings are cast in and purified together by the fire; with the addition of the stone pyrimachus which is found there in abundance." Thus do numerous sorts of things contain in their various substances notably and abundantly this element of iron and earth. However, there are many stones, and very common ones, found in every soil, also earths, and various and mixed materials, which do not hold rich substances, but yet have their own iron elements, and yield them to skilfully-made fires, yet which are left aside by metallick men because they are less profitable; while other soils give some show of a ferruginous nature, yet (being very barren) are hardly ever smelted down into iron; and being neglected are not generally known. Manufactured irons differ very greatly amongst themselves. For one kind is tenacious in its nature, and this is the best; one is of medium quality: another is brittle, and this is the worst. Sometimes the iron, by reason of the excellency of the ore, is wrought into steel, as to-day in Noricum. From the finest iron, too, well wrought and purged from all dross, or by being plunged in water after heating, there issues what the Greeks call στόμωμα; the Latins *acies;* others *aciarium,* such as was at times called Syrian, Parthian, Noric, Comese, Spanish; elsewhere it is named from the water in which it is so often plunged, as at Como in Italy[75], Bambola and Tarazona in Spain. *Acies* fetches a much larger price than mere iron. And owing to its superiority it better accords with the loadstone, from which more powerful quality it is often smelted, and it acquires the virtues from it more quickly, retains them longer at their full, and in the best condition for magnetical experiments. After iron has been smelted in the first furnaces, it is afterward wrought by various arts in large worksteads or mills, the metal acquiring consistency when hammered with ponderous blows, and throwing off the dross. After the first smelting it is rather brittle and by no means perfect. Wherefore with us (English) when the larger military

guns are cast, they purify the metal from dross more fully, so that they may be stronger to withstand the force of the firing; and they do this by making it pass again (in a fluid state) through a chink, by which process it sheds its recremental matter. Smiths render iron sheets tougher with certain liquids, and by blows of the hammer, and from them make shields and breastplates that defy the blows of battle-axes. Iron becomes harder through skill and proper tempering, but also by skill turns out in a softer condition and as pliable as lead. It is made hard by the action of certain waters into which while glowing it is plunged, as at Bambola and Tarazona in Spain: It grows soft again, either by the effect of fire alone, when without hammering and without water, it is left to cool by itself; or by that of grease into which it is plunged; or (that {24} it may the better serve for various trades) it is tempered variously by being skilfully besmeared. Baptista Porta expounds this art in book 13 of his *Magia Naturalis*. Thus this ferric and telluric nature is included and taken up in various bodies of stones, ores, and earths; so too it differs in aspect, in form, and in efficiency. Art smelts it by various processes, improves it, and turns it, above all material substances, to the service of man in trades and appliances without end. One kind of iron is adapted for breastplates, another serves as a defence against shot, another protects against swords and curved blades (commonly called scimitars), another is used for making swords, another for horseshoes. From iron are made nails, hinges, bolts, saws, keys, grids, doors, folding-doors, spades, rods, pitchforks, hooks, barbs, tridents, pots, tripods, anvils, hammers, wedges, chains, hand-cuffs, fetters, hoes, mattocks, sickles, baskets, shovels, harrows, planes, rakes, ploughshares, forks, pans, dishes, ladles, spoons, spits, knives, daggers, swords, axes, darts, javelins, lances, spears, anchors, and much ship's gear. Besides these, balls, darts, pikes, breastplates, helmets, cuirasses, horseshoes, greaves, wire, strings of musical instruments, chairs, portcullises, bows, catapults, and (pests of human kind) cannon, muskets, and cannon-balls, with endless instruments unknown to the Latins: which things I have rehearsed in order that it may be understood how great is the use of iron, which surpasses a hundred times that of all the other metals; and is day by day being wrought by metal-workers whose stithies are found in almost every village. For this is the foremost of metals, subserving many and the greatest needs of man, and abounds in the earth above all other metals, and is predominant. Wherefore those Chemists are fools[76] who think that nature's will is to perfect all metals into gold; she might as well be making ready to change all stones to diamonds, since diamond surpasses all in splendour and hardness, because gold excels in splendour, gravity, and density, being invincible against all deterioration. Iron as dug up is therefore, like iron that has been smelted, a metal, differing a little indeed from the primary homogenic terrestrial body, owing to the metallick humour it has imbibed; yet not so alien as that it will not, after the manner of refined matter, admit largely of the magnetick forces, and may be associated with that prepotent form belonging to the earth, and yield to it a due submission.

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CHAP. VIII.

In what countries and districts iron *originates.*

Plenty of iron mines exist everywhere, both those of old time recorded in early ages by the most ancient writers, and the new and modern ones. The earliest and most important seem to me to be those of Asia. For in those countries which abound naturally in iron, governments and the arts flourished exceedingly, and things needful for the use of man were discovered and sought after. It is recorded to have been found about Andria, in the region of the Chalybes near the river Thermodon in Pontus; in the mountains of Palestine which face Arabia; in Carmania: in Africa there was a mine of iron in the Isle of Meroe; in Europe in the hills of Britain, as Strabo writes; in Hither Spain, in Cantabria. Among the Petrocorii and Cubi Biturges[77] (peoples of Gaul), there were worksteads in which iron used to be wrought. In greater Germany near Luna, as recorded by Ptolemy; Gothinian iron is mentioned by Cornelius Tacitus; Noric iron is celebrated in the verses of poets; and Cretan, and that of Eubœa; many other iron mines were passed over by these writers or unknown to them; and yet they were neither poor nor scanty, but most extensive. Pliny[78] says that Hither Spain and all the district from the Pyrenees is ferruginous, and on the part of maritime Cantabria washed by the Ocean (says the same writer) there is (incredible to relate) a precipitously high mountain wholly composed of this material. The most ancient mines were of iron rather than of gold, silver, copper or lead; since mainly this was sought because of the demand; and also because in every district and soil they were easy to find, not so deep-lying, and less beset by difficulties. If, however, I were to enumerate modern iron workings, and those of this age and over Europe only, I should have to write a large and bulky volume, and sheets of paper would run short quicker than the iron, and yet for one sheet they could furnish a thousand worksteads. For amongst minerals, no material is so ample; all metals, and all stones distinct from iron, are outdone by ferric and ferruginous matter. For you will not readily find any region, and scarcely any country district over the whole of Europe (if you search at all deeply), that does not either produce a rich and abundant vein of iron or some soil containing or slightly charged with ferruginous stuff; and that this is true any expert in the arts of metals and chemistry will easily {26} find. Beside that which has ferruginous nature, and the metallick lode, there is another ferric substance which does not yield the metal in this way because its thin humour is burnt out by fierce fires, and it is changed into an iron slag like that which is separated from the metal in the

first furnaces. And of this kind is all clay and argillaceous earth, such as that which apparently forms a large part of the whole of our island of Britain: all of which, if subjected very vehemently to intense heat, exhibits a ferric and metallick body, or passes into ferric vitreous matter, as can be easily seen in buildings in bricks baked from clay, which, when placed next the fires in the open kilns (which our folk call *clamps*)[79] and burned, present an iron vitrification, black at the other end. Moreover all those earths as prepared are drawn by the magnet, and like iron are attracted by it. So perpetual and ample is the iron offspring of the terrestrial globe. Georgius Agricola says that almost all mountainous regions are full of its ores, while as we know a rich iron lode is frequently dug in the open country and plains over nearly the whole of England and Ireland; in no other wise than as, says he, iron is dug out of the meadows at the town of Saga in pits driven to a two-foot depth. Nor are the West Indies without their iron lodes, as writers tell us; but the Spaniards, intent upon gold, neglect the toilsome work of iron-founding, and do not search for lodes and mines abounding in iron. It is probable that nature and the globe of the earth are not able to hide, and are evermore bringing to the light of day, a great mass of inborn matter, and are not invariably obstructed by the settling of mixtures and efflorescences at the earth's surface. It is not only in the common mother (the terrestrial globe) that iron is produced, but sometimes also in the air from the earth's exhalations, in the highest clouds. It rained iron in Lucania, the year in which M. Crassus was slain. The tale is told, too, that a mass of iron, like slag, fell from the air in the Nethorian forest, near Grina, and they narrate that the mass was many pounds in weight; so that it could neither be conveyed to that place, on account of its weight, nor be brought away by cart, the place being without roads. This happened before the civil war waged between the rival dukes in Saxony. A similar story, too, comes to us from Avicenna. It once rained iron in the Torinese[80], in various places (Julius Scaliger telling us that he had a piece of it in his house), about three years before that province was taken over by the king. In the year 1510 in the country bordering on the river Abdua (as Cardan writes[81] in his book *De Rerum Varietate*) there fell from the sky 1200 stones, one weighing 120 pounds, another 30 or 40 pounds, of a rusty iron colour and remarkably hard. These occurrences being rare are regarded as portents, like the showers of earth and stones mentioned in Roman history. But that it ever rained other metals is not recorded; for it has never been known to rain from the sky gold, {27} silver, lead, tin, or spelter[82]. Copper, however, has been at some time noticed to fall from the sky, and this is not very unlike iron; and in fact cloud-born iron of this sort, or copper, are seen to be imperfectly metallick, incapable of being cast in any way, or wrought with facility. For the earth hath of her store plenty of iron in her highlands, and the globe contains the ferric and magnetick element in rich abundance. The exhalations forcibly derived from such material may well become concreted in the upper air by the help of more powerful causes, and hence some monstrous progeny of iron be begotten.

CHAP. IX.

Iron ore attracts iron ore.

* From various substances iron (like all the rest of the metals) is extracted: such substances being stones, earth, and similar concretions which miners call veins because it is in veins[83], as it were, that they are generated. We have spoken above of the variety of these veins. If a properly coloured ore of iron and a rich one (as miners call it) is placed, as soon as mined, upon water in a bowl or any small vessel (as we have shown before in the case of a loadstone), it is attracted by a similar piece of ore brought near by hand, yet not so powerfully and quickly as one loadstone is drawn by another loadstone, but slowly and feebly. Ores of iron that are stony, cindery, dusky, red, and several more of other colours, do not attract one another mutually, nor are they attracted by the loadstone itself, even by a strong one, no more than wood, or lead, silver, or gold. Take those ores and burn, or rather roast them, in a moderate fire, so that they are not suddenly split up, or fly asunder, keeping up the fire ten or twelve hours, and gently increasing it, then let them grow cold, skill being shown in the direction in which they are placed: These ores thus prepared a loadstone will now draw, and they now show a mutual sympathy, and when skilfully arranged run together by their own forces.

CHAP. X.

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* Iron ore has poles, and acquires them, and settles *itself toward the poles of the universe.*

Deplorable is man's ignorance in natural science, and modern philosophers, like those who dream in darkness, need to be aroused, and taught the uses of things and how to deal with them, and to be induced to leave the learning sought at leisure from books alone, and that is supported only by unrealities of arguments and by conjectures. For the knowledge of iron (than which nothing is in more common use), and that of many more substances around us, remains unlearned; iron, a rich ore of which, placed in a vessel upon

water, by an innate property of its own directs itself, just like the loadstone, North and South, at which points it rests, and to which, if it be turned aside, it reverts by its own inherent vigour. But many ores, less perfect in their nature, which yet contain amid stone or earthy substances plenty of iron, have no such motion; but when prepared by skilful treatment in the fires, as shown in the foregoing chapter, they acquire a polar vigour (which we call verticity[84]); and not only the iron ores in request by miners, but even earth merely charged with ferruginous matter, and many rocks, do in like manner tend and lean toward those portions of the heavens, or more truly of the earth, if they be skilfully placed, until they reach the desired location, in which they eagerly repose.

CHAP. XI.

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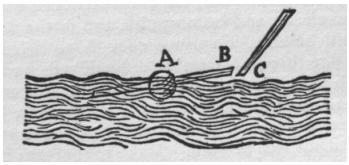
* Wrought Iron, not excited by a loadstone, *draws iron.*

From the ore, which is converted, or separated, partly into metal, partly into slag, by the intense heat of fires, iron is smelted in the first furnaces in a space of eight, ten, or twelve hours, and the metal flows away from the dross and useless matter, forming a large and long mass, which being subjected to a sharp hammering is cut into parts, out of which when reheated in the second hearth of the forge, and again placed on the anvil, the smiths fashion quadrangular lumps, or more specially bars which are bought by merchants and blacksmiths, from which in smithies usually it is the custom to fashion the various implements. This iron we term *wrought*, and its attraction by the loadstone is manifest to all. But we, by more carefully trying everything[85], have found out that iron merely, by itself alone, not excited by any loadstone, not charged by any alien forces, attracts other iron; though it does not so eagerly snatch and suddenly pluck at it as would a fairly strong loadstone; this you may know thus: A small piece of cork, the size of a hazel-nut, rounded, is traversed by an iron wire up to the middle of the wire: when set swimming on still water apply to one end of it, close (yet so as not to touch), the end of another iron wire; and wire draws wire, and one follows the other when slowly drawn back, and this goes on up to the proper boundaries. Let A be the cork with the iron wire, B one end of it raised a little above the surface of the water, C the end of the second wire, showing the way in which B is drawn by C. You may prove it in another way in a larger body. Let a long bright iron rod (such as is made for hangings and window curtains) be hung in balance by a slender silken cord: to one end of this as it rests in the air bring a small oblong mass of polished iron, with its proper end at the distance of half a digit. The balanced iron {30} turns itself to the mass; do you with the same quickness draw back the mass in your hand in a circular path about the point of equilibrium of the suspension; the end of the balanced iron follows after it, and turns in an orbit.



CHAP. XII.

* A long piece of Iron, even though not excited by a *loadstone, settles itself toward North and South.*

Every good and perfect piece of iron, if drawn out in length, points North and South, just as the loadstone or iron rubbed with a magnetical body does; a thing that our famous philosophers have little understood, who have sweated in vain to set forth the magnetick virtues and the causes of the friendship of iron for the stone. You may experiment with either large or small iron works, and either in air or in water. A straight piece of iron six feet long of the thickness of your finger is suspended (in the way described in the foregoing chapter) in exact æquipoise by a strong and slender silken cord. But the cord should be cross-woven of several silk filaments, not twisted simply in one way; and it should be in a small chamber with all doors and windows closed, that the wind may not enter, nor the air of the room be in any way disturbed; for which reason it is not expedient that the trial should be made on windy days, or while a storm is brewing. For thus it freely follows its bent, and slowly moves until at length, as it rests, it points with its ends North and South, just as iron touched with a loadstone does in shadow-clocks, and in compasses, and in the mariners' compass. You will be able, if curious enough, to balance all at the same time by fine threads a number of small rods, or iron wires, or long pins with which women knit stockings; you will see that all of them at the same time are in accord, unless there be some error in this delicate operation: for unless you prepare everything fitly and skilfully, the labour will be void. Make trial

of this thing in water also, which is done both more certainly and more easily. Let an iron wire two or three digits long, more or less, be passed through a round cork, so that it may just float upon water; and as soon as you have committed it to the waves, it turns upon its own centre, and one end tends to the North, the other to the South; the causes of which you will afterwards find {31}
* in the laws of the direction. This too you should understand, and hold firmly in memory, that as a strong loadstone, and iron touched with the same, do not invariably point exactly to the true pole but to the point of the variation; so does a weaker loadstone, and so does the iron, which directs itself by its own forces only, not by those impressed by the stone; and so every ore of iron, and all bodies naturally endowed with something of the iron nature, and prepared, turn to the same point of the horizon, according to the place of the variation in that particular region (if there be any variation therein), and there abide and rest.

CHAP. XIII.

* Wrought iron has in itself certain parts Boreal and Austral: A magnetick vigour, verticity, and determinate *vertices, or poles*.

ron settles itself toward the North and South; not with one and the same point toward this pole or that: for one end of the piece of ore itself and one extremity also of a wrought-iron wire have a sure and constant destination to the North, the other to the South, whether the iron hang in the air, or float on water, be the iron large rods or thinner wires. Even if it be a little rod, or a wire ten or twenty or more ells in length; one end as a rule is Boreal, the other Austral. If you cut off part of that wire, and if the end of that divided part were Boreal, the other end (which was joined to it) will be Austral. Thus if you divide it into several parts, before making an experiment on the surface of water, you can recognize the vertex[86]. In all of them a Boreal end draws an Austral and repels a Boreal, and contrariwise, according to the laws magnetical. Yet herein wrought iron differs from the loadstone and from its own ore, inasmuch as in an iron ball of any size, such as those used for artillery or cannon, or bullets used for carbines or fowling-pieces, verticity is harder to acquire and is less apparent than in a piece of loadstone, or of ore itself, or than in a round loadstone. But in long and extended pieces of iron a power is at once discerned; the causes of which fact, and the methods by which it acquires its verticity and its poles without use of a loadstone, as well as the reasons for all the other obscure features of verticity, we shall set forth in describing the motion of direction.

CHAP. XIIII. {32}

Concerning other powers of loadstone, and its *medicinal properties*.

ioscorides prescribes loadstone to be given with sweetened water, three scruples' weight, to expel gross humours. Galen writes that a like quantity of bloodstone avails. Others relate that loadstone perturbs the mind and makes folk melancholick, and mostly kills. Gartias ab Horto[87] thinks it not deleterious or injurious to health. The natives of East India tell us, he says, that loadstone taken in small doses preserves youth. On which account the aged king, Zeilam, is said to have ordered the pans in which his victuals were cooked to be made of loadstone. The person (says he) to whom this order was given told me so himself. There are many varieties of loadstone produced by differences in the mingling of earths, metals, and juices; hence they are altogether unlike in their virtues and effects, due to propinquities of places and of agnate bodies, and arising from the pits themselves as it were from the matrices being soul. One loadstone is therefore able to purge the stomach, and another to check purging, to cause by its fumes a serious shock to the mind, to produce a gnawing at the vitals, or to bring on a grave relapse; in case of which ills they exhibit gold and emerald, using an abominable imposture for lucre. Pure loadstone may, indeed, be not only harmless, but even able to correct an over-fluid and putrescent state of the bowels and bring them back to a better temperament; of this sort usually are the oriental magnets from China, and the denser ones from Bengal, which are neither misliking nor unpleasant to the actual senses. Plutarch and Claudius Ptolemy[88], and all the copyists since their time, think that a loadstone smeared with garlick does not allure iron. Hence some suspect that garlick is of avail against any deleterious power of the magnet: thus in philosophy many false and idle conjectures arise from fables and falsehoods. Some physicians[89] have that a loadstone has power to extract the iron of an arrow from the human body. But it is when whole that the loadstone draws, not when pulverized and formless, buried in plasters; for it does not attract by reason of its material, but is rather adapted for the healing of open wounds, by reason of exsiccation, closing up and drying the sore, an effect by which the arrow-heads would rather be retained in the wounds. Thus vainly and preposterously do the sciolists look for remedies while ignorant of the true causes of things. The application of a {33}
loadstone for all sorts of headaches no more cures them (as some make out) than would an iron

helmet or a steel cap. To give it in a draught to dropsical persons is an error of the ancients, or an impudent tale of the copyists, though one kind of ore may be found which, like many more minerals, purges the stomach; but this is due to some defect of that ore and not to any magnetick property. Nicolaus puts a large quantity of loadstone into his divine plaster[90], just as the Augsburgers do into a black plaster[91] for fresh wounds and stabs; the virtue of which dries them up without smart, so that it proves an efficacious medicament. In like manner also Paracelsus to the same end mingles it in his plaster for stab wounds[92].

CHAP. XV.

The Medicinal Virtue of Iron.[93]

Not foreign to our present purpose will it be to treat briefly also of the medicinal virtue of iron: for it is a prime remedial for some diseases of the human body, and by its virtues, both those that are natural and those acquired by suitable preparation, it works marvellous changes in the human body, so that we may the more surely recognize its nature through its medicinal virtue and through certain manifest experiments. So that even those tyros in medicine who abuse this most famous medicament may learn to prescribe it with better judgment for the healing of the sick, and not, as too often they use it, to their harm. The best iron, Stomoma, or Chalybs, Acies, or Aciarium, is reduced to a fine powder by a file; the powder is steeped in the sharpest vinegar, and dried in the sun, and again soused in vinegar, and dried; afterwards it is washed in spring water or other suitable water, and dried; then for the second time it is pulverized and reduced on porphyry, passed through a very fine sieve, and put back for use. It is given chiefly in cases of laxity and over-humidity of the liver, in enlargement of the spleen, after due evacuations; for which reason it restores young girls when pallid, sickly, and lacking colour, to health and beauty; since it is very siccative, and is astringent without harm. But some who in every internal malady always talk of obstruction of the {34}
liver and spleen, think it beneficial in those cases because it removes obstructions, mainly trusting to the opinions of certain Arabians[94]: wherefore they administer it to the dropsical and to those suffering from tumour of the liver or from chronic jaundice, and to persons troubled with hypochondrical melancholia or any stomachic disorder, or add it to electuaries, without doubt to the grievous injury of many of their patients. Fallopius commends it prepared in his own way for tumours of the spleen, but is much mistaken; for loadstone is pre-eminently good for spleens relaxed with humour, and swollen; but it is so far from curing spleens thickened into a tumour that it mightily confirms the malady. For those drugs which are strong siccatives and absorb humour force the viscera when hardened into a tumour more completely into a quasi-stony body. There are some who roast iron in a closed oven with fierce firing, and burn it strongly, until it turns red, and they call this Saffron of Mars; which is a powerful siccative, and more quickly penetrates the intestines. Moreover they order violent exercise, that the drug may enter the viscera while heated and so reach the place affected; wherefore also it is reduced to a very fine flour; otherwise it only sticks in the stomach and in the chyle and does not penetrate to the intestines. As a dry and earthy medicament, then, it is shown by the most certain experiments to be, after proper evacuations, a remedy for diseases arising from humour (when the viscera are charged and overflowing with watery rheum). Prepared steel is a medicament proper for enlarged spleen. Iron waters too are effectual in reducing the spleen, although as a rule iron is of a frigid and astringent efficiency, not a laxative; but it effects this neither by heat nor by cold, but from its own dryness when mixed with a penetrative fluid: it thus disperses the humour, thickens the villi, hardens the tissues, and contracts them when lax; while the inherent heat in the member thus strengthened, being increased in power, dissipates what is left. Whereas if the liver be hardened and weakened by old age or a chronic obstruction, or the spleen be shrivelled and contracted to a schirrus, by which troubles the fleshy parts of the limbs grow flaccid, and water under the skin invades the body, in the case of these conditions the introduction of iron accelerates the fatal end, and considerably increases the malady. Amongst recent writers there are some who in cases of drought of the liver prescribe, as a much lauded and famous remedy, the electuary of iron slag, described by Rhazes[95] in his ninth book *ad Almansorem*, Chap. 63, or prepared filings of steel; an evil and deadly advice: which if they do not some time understand from our philosophy, at least everyday experience, and the decline and death of their patients, will convince them, even the sluggish and lazy. Whether iron be warm or cold is variously contended by many. By Manardus, Curtius, Fallopius and others, many reasons are adduced on {35}
both sides; each settles it according to his own sentiment. Some make it to be cold, saying that iron has the property of refrigerating, because Aristotle in his *Meteorologica* would put iron in the class of things which grow concreted in cold by emission of the whole of their Heat: Galen, too, says that iron has its consistency from cold; also that it is an earthy and dense body. Further that iron is astringent, also that Chalybeate water quenches thirst: and they adduce the cooling effect of thermal iron waters. Others, however, maintain that it is Warm, because of Hippocrates making out that waters are warm which burst forth from places where iron exists. Galen says that in all metals there is considerable substance, or essence, of fire. Paolo[96] affirms that iron waters are warm. Rhazes will have it that iron is warm and dry in the third degree. The Arabians think that it opens the spleen and liver; wherefore also that iron is warm. Montagnana recommends it in cold affections of the uterus and stomach. Thus do the smatterers cross swords

together, and puzzle inquiring minds by their vague conjectures, and wrangle for trifles as for goats' wool, when they philosophize, wrongly allowing and accepting properties: but these matters will appear more plainly by and by when we begin to discuss the causes of things; the clouds being dispersed that have so darkened all Philosophy. Filings, scales, and slag of iron are, as Avicenna makes out, not wanting in deleterious power (haply when they are not well prepared or are taken in larger quantity than is fit), hence they cause violent pain in the bowels, roughness of the mouth and tongue, marasmus, and shrivelling of the limbs. But Avicenna wrongly[97] and old-womanishly makes out that the proper antidote to this iron poison is loadstone to the weight of a drachm taken as a draught in the juice of mercurialis or of Beet; for loadstone is of a twofold nature, usually malefiant and pernicious, nor does it resist iron, since it attracts it; nor when drunk in a draught in the form of powder does it avail to attract or repel, but rather inflicts the same evils.

CHAP. XVI.

{36}

That loadstone & iron ore are the same, but iron an *extract from both, as other metals are from their own* ores; & that all magnetick virtues, though *weaker, exist in the ore itself & in smelted iron.*

Hitherto we have declared the nature & powers of the loadstone, & also the properties & essence of iron; it now remains to show their mutual affinities, & kinship, so to speak, & how very closely conjoined these substances are. At the highest part of the terrestrial globe, or at its perishable surface & rind, as it were, these two bodies usually originate & are produced in one and the same matrix, as twins in one mine. Strong loadstones are dug up by themselves, weaker ones too have their own proper vein. Both are found in iron mines. Iron ore most often occurs alone, without strong loadstone (for the more perfect are rarely met with). Strong loadstone is a stone resembling iron; out of it is usually smelted the finest iron, which the Greeks call *stomoma*, the Latins *acies*, the Barbarians (not amiss) *aciare*, or *aciarium*. This same stone draws, repels, controls other loadstones, directs itself to the poles of the world, picks up smelted iron, and works many other wonders, some already set forth by us, but many more which we must demonstrate more fully. A weaker loadstone, however, will exhibit all these powers, but in a lesser degree; while iron ore, & also wrought iron (if they have been prepared) show their strength in all magnetick experiments not less than do feeble
* and weak loadstones; & an inert piece of ore, & one possessed of no magnetick properties, & just thrown out[98] of the pit, when roasted in the fire & prepared with due art (by the elimination of
* humours & foreign excretions) awakes, and becomes in power & potency a magnet, occasionally a stone or iron ore is mined, which attracts forthwith without being prepared: for native iron of the right colour attracts and governs iron magnetically. One form then belongs to the one mineral, one species, one self-same essence. For to me there seems to be a greater difference, & unlikeness, between the strongest loadstone, & a weak one which scarce can attract a single chip {37} of iron; between one that is stout, strong, metallick, & one that is soft, friable, clayey; amidst such variety of colour, substance, quality, & weight; than there is on the one hand between the best ore, rich in iron, or iron that is metallick from the beginning, and on the other the most excellent loadstone. Usually, too, there are no marks to distinguish them, and even metallurgists cannot decide between them, because they agree together in all respects. Moreover we see that the best loadstone and the ore of iron are both as it were distressed by the same maladies & diseases, both run to old age in the same way & exhibit the same marks of it, are preserved & keep their properties by the same remedies & safeguards; & yet again the one increases the potency of the other, & by artfully devised adjuncts marvellously intensifies, & exalts it. For both are impaired by the more acrid juices as by poisons, & the aqua fortis of the Chemists inflicts on both the same wounds, and when exposed too long to harm from the atmosphere, they both alike pine away, so to speak, & grow old; each is preserved by being kept in the dust & scrapings of the other; & when a fit piece of steel or iron is adjoined above its pole, the loadstone's vigour is augmented through the firm union. The loadstone is laid up in iron filings, not that iron is its food; as though loadstone were alive and needed feeding, as Cardan philosophizes[99]; nor yet that so it is delivered from the inclemency of the weather (for which cause it as well as iron is laid up in bran by Scaliger; mistakenly, however, for they are not preserved well in this way, and keep for years their own fixed forms): nor yet, since they remain perfect by the mutual action of their powders, do their extremities waste away, but are cherished & preserved, like by like. For just as in their own places, in the mines, bodies like to each other endure for many ages entire and uncorrupt, when surrounded by bodies of the same stuff, as the lesser interior parts in a great mass: so loadstone and ore of iron, when inclosed in a mound of the same material, do not exhale their native humour, do not waste away, but retain their soundness. A loadstone lasts longer in filings of smelted iron, & a piece of iron ore excellently also in dust of loadstone; as also smelted iron in filings of loadstone & even in those of iron. Then both these allied bodies have a true & just form of one & the same species; a form which until this day was considered by all, owing to their outward unlikeness & the inequality of the potency that is the same innate in both, to be different & unlike in kind; the smatterers not understanding that the same powers, though

differing in strength, exist in both alike. And in fact they both are true & intimate parts of the earth, & as such retain the prime natural properties of mutually attracting, of moving, & of disposing themselves toward the position of the world, and of the terrestrial globe; which {38} properties they also impart to each other, and increase, confirm, receive, and retain each other's forces. The stronger fortifies the weaker, not as though aught were taken away from its own substance, or its proper vigour, nor because any corporeal substance is imparted, but the dormant virtue of the one is aroused by the other, without loss. For if with a single small stone you touch a thousand bits of iron for the use of mariners[100], that loadstone attracts iron no less strongly than before; with the same stone weighing one pound, any one will be able to suspend in the air a thousand pounds of iron. For if any one were to fix high up on the walls so many iron nails of so great a weight, & were to apply to them the same number of nails touched, according to the art, by a loadstone, they would all be seen to hang in the air through the force of one small stone. So this is not solely the action, labour, or outlay of the loadstone; but the iron, which is in a sense an extract from loadstone, and a fusion of loadstone into metal, & conceives vigour from it, & by proximity strengthens the magnetick faculties, doth itself, from whatever lode it may have come, raise its own inborn forces through the presence & contact of the stone, even when solid bodies intervene. Iron that has been touched, acts anew on another piece of iron by contact, & adapts it for magnetick movements, & this again a third. But if you rub with a loadstone any other metal, or wood, or bones, or glass, as they will not be moved toward any particular and determinate quarter of heaven, nor be attracted by any magnetick body, so they are able not to impart any magnetick property to other bodies or to iron itself by attrition, & by infection. Loadstone differs from iron ore, as also from some weaker magnets, in that when molten in the furnace into a ferric & metallick fused mass, it does not so readily flow & dissolve into metal; but is sometimes burnt to ashes in large furnaces; a result which it is reasonable to suppose arises from its having some kind of sulphureous matter mixed with it, or from its own excellence & simpler nature, or from the likeness & common form which it has with the common mother, the Great Magnet. For earths, and iron stones, magnets abounding in metal, are the more imbued & marred with excrementitious metallick humours, and earthy corruptions of substance, as numbers of loadstones are weaker from the mine; hence they are a little further remote from the common mother, & are degenerate, & when smelted in the furnace undergo fusion more easily, & give out a more certain metallick product, & a metal that is softer, not a tough steel. The majority of loadstones (if not unfairly burnt[101]) yield in the furnace a very excellent iron. But iron ore also agrees in all those primary qualities with loadstone; for both, being nearer and more closely akin to the earth above all bodies known to us, have in themselves a magnetick substance, & one {39} that is more homogenic, true & cognate with the globe of the earth; less infested & spoiled by foreign blemish; less confused with the outgrowths of earth's surface, & less debased by corrupt products. And for this reason Aristotle in the fourth book of his *Meteora* seems not unfairly to separate iron from all the rest of the metals. Gold, he says, silver, copper, tin, lead, belong to water; but iron is of the earth. Galen, in the fourth chapter of *De Facultatibus Simplicium Medicamentorum*, says that iron is an earthy & dense body. Accordingly a strong loadstone is on our showing especially of the earth: the next place is occupied by iron ore or weaker loadstone; so the loadstone is by nature and origin[102]** of iron, and it and magnetick iron are both one in kind. Iron ore yields iron in furnaces; loadstone also pours forth iron in the furnaces, but of a much more excellent sort, that which is called steel or blade-edge; and the better sort of iron ore is a weak loadstone, the best loadstone being a most excellent ore of iron, in which, as is to be shown by us, the primary properties are grand and conspicuous. Weaker loadstone or iron ore is that in which these properties are more obscure, feeble, and are scarce perceptible to the senses.

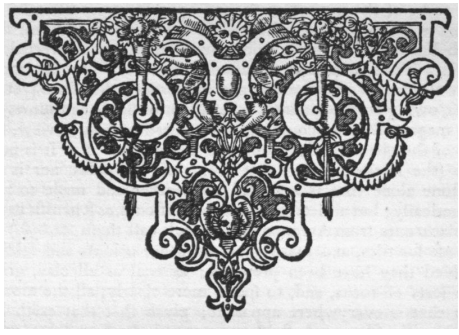
CHAP. XVII.

That the globe of the earth is magnetick, & a magnet; & *how in our hands the magnet stone has all the primary* forces of the earth, while the earth by the *same powers remains constant in a fixed direction in the universe.*

rior to bringing forward the causes of magnetical motions, & laying open the proofs of things hidden for so many ages, & our experiments (the true foundations of terrestrial philosophy), we have to establish & present to the view of the learned our New & unheard of doctrine about the earth; and this, when argued by us on the grounds of its probability, with subsequent experiments & proofs, will be as certainly assured as {40} anything in philosophy ever has been considered & confirmed by clever arguments or mathematical proofs. The terrene mass, which together with the vasty ocean produces the sphærick figure & constitutes our globe, being of a firm & constant substance, is not easily changed, does not wander about, & fluctuate with uncertain motions, like the seas, & flowing waves: but holds all its volume of moisture in certain beds & bounds, & as it were in oft-met veins, that it may be the less diffused & dissipated at random. Yet the solid magnitude of the earth prevails & reigns supreme in the nature of our globe. Water, however, is attached to it, & as an appendage only, & a flux emanating from it; whose force from the beginning is conjoined

with the earth through its smallest parts, and is innate in its substance. This moisture the earth as it grows hot throws off freely when it is of the greatest possible service in the generation of things. But the thews and dominant stuff of the globe is that terrene body which far exceeds in quantity all the volume of flowing streams and open waters (whatever vulgar philosophers may dream of the magnitudes and proportions of their elements), and which takes up most of the whole globe and almost fills it internally, and by itself almost suffices to endow it with sphærick shape. For the seas only fill certain not very deep or profound hollows, since they rarely go down to a depth of a mile and generally do not exceed a hundred or 50 fathoms. For so it is ascertained by the observations of seamen when by the plumb-line and sinker its abysms are explored with the nautical sounder; which depths relatively to the dimensions of the globe, do not much deform its globular shape. Small then appears to be that portion of the real earth that ever emerges to be seen by man, or is turned up; since we cannot penetrate deeper into its bowels, further than the wreckage of its outer efflorescence, either by reason of the waters which gush up in deep workings, as through veins, or for want of a wholesome air to support life in the miners, or on account of the vast cost that would be incurred in pumping out such huge workings[103], and many other difficulties; so that to have gone down to a depth of four hundred, or (which is of rarest occurrence) of five hundred fathoms[104] as in a few mines, appears to all a stupendous undertaking. But it is easy to understand how minute, how almost negligibly small a portion that 500 fathoms is of the earth's diameter, which is 6,872 miles. It is then parts only of the earth's circumference and of its prominences that are perceived by us with our senses; and these in all regions appear to us to be either loamy, or clayey, or sandy, or full of various soils, or marls: or lots of stones or gravel meet us, or beds of salt, or a metallick lode, and metals in abundance. In the sea and in deep waters, however, either reefs, and huge boulders, or smaller stones, or sands, or mud are found by mariners as they sound the depths. Nowhere does the Aristotelian {41}
element of *earth* come to light; and the Peripateticks are the sport of their own vain dreams about elements. Yet the lower bulk of the earth and the inward parts of the globe consist of such bodies; for they could not have existed, unless they had been related to and exposed to the air and water, and to the light and influences of the heavenly bodies, in like manner as they are generated, and pass into many dissimilar forms of things, and are changed by a perpetual law of succession. Yet the interior parts imitate them, and betake themselves to their own source, on the principle of terrene matter, albeit they have lost the first qualities and the natural terrene form, and are borne towards the earth's centre, and cohære with the globe of the earth, from which they cannot be wrenched asunder except by force. But the loadstone and all magneticks, not the stone only, but every magnetick homogenic substance, would seem to contain the virtue of the earth's core and of its inmost bowels, and to hold within itself and to have conceived that which is the secret and inward principle of its substance; and it possesses the actions peculiar to the globe of attracting, directing, disposing, rotating, stationing itself in the universe, according to the rule of the whole, and it contains and regulates the dominant powers of the globe; which are the chief tokens and proofs of a certain distinguishing combination, and of a nature most thoroughly conjoint. For if among actual bodies one sees something move and breathe, and experience sensations, and be inclined and impelled by reason, will one not, knowing and seeing this, conclude that it is a man or something rather like a man, than that it is a stone or a stick? The loadstone far excels all other bodies known to us in virtues and properties pertaining to the common mother: but those properties have been far too little understood or realized by philosophers: for to its body bodies magnetical rush in from all sides and cleave to it, as we see them do in the case of the earth. It has poles, not mathematical points, but natural termini of force excelling in primary efficiency by the co-operation of the whole: and there are poles in like manner in the earth which our forefathers sought ever in the sky: it has an æquator, a natural dividing line between the two poles, just as the earth has: for of all lines drawn by the mathematicians on the terrestrial globe, the æquator is the natural boundary, and is not, as will hereafter appear, merely a mathematical circle. It, like the earth, acquires Direction and stability toward North and South, as the earth does; also it has a circular motion toward the position of the earth, wherein it adjusts itself to its rule: it follows the ascensions and declinations of the earth's poles, and conforms exactly to the same, and by itself raises its own poles above the horizon naturally according to the law of the particular country and region, or sinks below it. The {42}
loadstone derives temporary properties, and acquires its verticity from the earth, and iron is affected by the verticity of the globe even as iron is by a loadstone: Magneticks are conformable to and are regulated by the earth, and are subject to the earth in all their motions. All its movements harmonize with, and strictly wait upon, the geometry and form of the earth, as we shall afterwards prove by most conclusive experiments and diagrams; and the chief part of the visible earth is also magnetical, and has magnetick motions, although it be disfigured by corruptions and mutations without end. Why then do we not recognize this the chief homogenic substance of the earth, likest of substances to its inner nature and closest allied to its very marrow? For none of the other mixed earths suitable for agriculture, no other metalliferous veins, nor stones, nor sand, nor other fragments of the earth which have come to our view possess such constant and peculiar powers. And yet we do not assume that the whole interior of this globe of ours is composed of stones or iron (although Franciscus Maurolycus, that learned man, deems the whole of the earth's interior to consist of solid stone). For not every loadstone that we have is a stone, it being sometimes like a clod, or like clay and iron either firmly compacted together out of various materials, or of a softer composition, or by heat reduced to the metallick state; and the magnetick substance by reason of its location and of its surroundings, and of the metallick matrix itself, is distinguished, at the surface of the terrene mass, by many qualities and adventitious natures, just as in clay it is marked by certain stones and iron lodes. But we maintain that the true earth is a solid substance, homogeneous with the globe, closely

coherent, endowed with a primordial and (as in the other globes of the universe) with a prepotent form; in which position it persists with a fixed verticity, and revolves with a necessary motion and an inherent tendency to turn, and it is this constitution, when true and native, and not injured or disfigured by outward defects, that the loadstone possesses above all bodies apparent to us, as if it were a more truly homogenic part taken from the earth. Accordingly native iron which *sui generis* (as metallurgists term it), is formed when homogenic parts of the earth grow together into a metallick lode; Loadstone being formed when they are changed into metallick stone, or a lode of the finest iron, or steel: so in other iron lodes the homogenic matter that goes together is somewhat more imperfect; just as many parts of the earth, even the high ground, is homogenic but so much more deformate. Smelted iron is fused and smelted out of homogenic stuffs, and cleaves to the earth more tenaciously than the ores themselves. Such then is our earth in its inward parts, possessed of a magnetick homogeneal nature, and upon such more perfect {43}
foundations as these rests the whole nature of things terrestrial, manifesting itself to us, in our more diligent scrutiny, everywhere in all magnetick minerals, and iron ores, in all clay, and in numerous earths and stones; while Aristotle's simple element, that most empty terrestrial phantom of the Peripateticks, a rude, inert, cold, dry, simple matter, the universal substratum, is dead, devoid of vigour, and has never presented itself to any one, not even in sleep, and would be of no potency in nature. Our philosophers were only dreaming when they spoke of a kind of simple and inert matter. Cardan does not consider the loadstone to be any kind of stone, "but a sort of perfected portion of some kind of earth that is absolute; a token of which is its abundance, there being no place where it is not found. And there is" (he says) "a power of iron in the wedded Earth which is perfect in its own kind when it has received fertilizing force from the male, that is to say, the stone of Hercules" (in his book *De Proportionibus*). And later: "Because" (he says) "in the previous proposition I have taught that iron is true earth." A strong loadstone shows itself to be of the inward earth, and upon innumerable tests claims to rank with the earth in the possession of a primary form, that by which Earth herself abides in her own station and is directed in her courses. Thus a weaker loadstone and every ore of iron, and nearly all clay, or clayey earth, and numerous other sorts (yet more, or less, owing to the different labefaction of fluids and slimes), keep their magnetick and genuine earth-properties open to view, falling short of the characteristic form, and deformate. For it is not iron alone (the smelted metal) that points to the poles, nor is it the loadstone alone that is attracted by another and made to revolve magnetically; but all iron ores, and other stones, as Rhenish slates and the black ones from Avignon (the French call them *Ardoises*) which they use for tiles, and many more of other colours and substances, provided they have been prepared; as well as all clay, grit[105], and some sorts of rocks, and, to speak more clearly, all the more solid earth that is everywhere apparent; given that that earth be not fouled with fatty and fluid corruptions; as mud, as mire, as accumulations of putrid matter; nor deformate by the imperfections of sundry admixtures; nor dripping with ooze, as marls; all are attracted by the loadstone, when simply prepared by fire, and freed from their refuse humour; and as by the loadstone so also by the earth herself they are drawn and controlled magnetically, in a way different from all other bodies; and by that inherent force settle themselves according to the orderly arrangement and fabric of the universe and of the Earth, as will appear later. Thus every part of the earth which is removed from it exhibits by sure {44}
experiments every impulse of the magnetick nature; by its various motions it observes the globe of the earth and the principle common to both.



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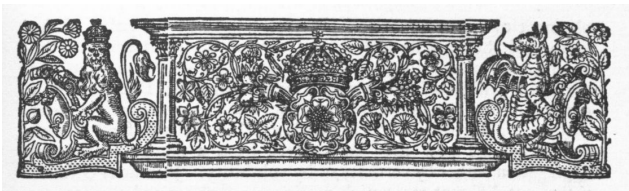


BOOK SECOND.

CHAP. I.

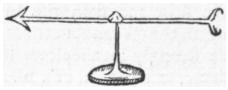
ON MAGNETICK
Motions.

Divers things concerning opinions about the magnet-stone, and its variety, concerning its poles and its known faculties, concerning iron, concerning the properties of iron, concerning a magnetick substance common to both of these and to the earth itself, have been spoken briefly by us in the former book. There remain the magnetical motions, and their fuller philosophy, shown and demonstrated. These motions are incitements of homogeneal parts either among themselves or toward the primary conformation of the whole earth. Aristotle admits only two simple motions of his elements, from the centre and toward the centre; of light ones upward, heavy ones downward; so that in the earth there exists one motion only of all its parts towards the centre of the world,—a rude and inert precipitation. But what of it is light, and how wrongly it is inferred by the Peripateticks from the simple motion of the elements, and also what is its heavy part, we will discuss elsewhere. But now our inquiry must be into the causes of other motions, depending on its true form, which we have plainly seen in our magnetick bodies; and these we have seen to be present in the earth and in all its homogenic parts also. We have noticed that they harmonize with the earth, and are bound up with its forces. Five movements[106] or differences of motions are then observed by us: Coition (commonly called attraction), the incitement to magnetick union; Direction towards the poles of {46}
the earth, and the verticity and continuance of the earth towards the determinate poles of the world; Variation, a deflexion from the meridian, which we call a perverted movement; Declination, a descent of the magnetick pole below the horizon; and circular motion, or Revolution. Concerning all these we shall discuss separately, and how they all proceed from a nature tending to aggregation, either by verticity or by volubility. Jofrancus Offusius[107] makes out different magnetick motions; a first toward a centre; a second toward a pole at seventy-seven degrees; a third toward iron; a fourth toward loadstone. The first is not always to a centre, but exists only at the poles in a straight course toward the centre, if the motion is magnetick; otherwise it is only motion of matter toward its own mass and toward the globe. The second toward a pole at seventy-seven degrees is no motion, but is direction with respect to the pole of the earth, or variation. The third and fourth are magnetick and are the same. So he truly recognizes no magnetick motion except the Coition toward iron or loadstone, commonly called attraction. There is another motion in the whole earth, which does not exist towards the terrella or towards its parts; videlicet, a motion of aggregation, and that movement of matter, which is called by philosophers a right motion, of which elsewhere.

CHAP. II.

On the Magnetick Coition, and first on the
Attraction of Amber, or more truly, on the
Attaching of Bodies to Amber.

Celebrated has the fame of the loadstone and of amber ever been in the memoirs of the learned. Loadstone and also amber do some philosophers invoke when in explaining many secrets their senses become dim and reasoning cannot go further. Inquisitive theologians also would throw light on the divine mysteries set beyond the range of human sense, by means of loadstone and amber; just as idle Metaphysicians, when they are setting up and teaching useless phantasms, have recourse to the loadstone as if it were a Delphick sword, an illustration always applicable to everything. But physicians even (with the authority of Galen), desiring to confirm the belief in the attraction of purgative medicines by {47}
means of the likeness of substance and the familiarities of the juices—truly a vain and useless error—bring in the loadstone as witness as being a nature of great authority and of conspicuous efficacy and a remarkable body. So in very many cases there are some who, when they are pleading a cause and cannot give a reason for it, bring in loadstone and amber as though they were personified witnesses. But these men (apart from that common error) being ignorant that the causes of magnetical motions are widely different from the forces of amber, easily fall into error, and are themselves the more deceived by their own cogitations. For in other bodies a conspicuous force of attraction manifests itself otherwise than in loadstone; like as in amber, concerning which some things must first be said, that it may appear what is that attaching of bodies, and how it is different from and foreign to the magnetical actions; those mortals being still ignorant, who think that inclination to be an attraction, and compare it with the magnetick coitions. The Greeks call it ἤλεκτρον[108] because it attracts straws to itself, when it is warmed by rubbing; then it is called ἅρπαξ[109]; and χρυσοφόρον from its golden colour. But the Moors call it Carabe[110], because they are accustomed to offer the same in sacrifices and in the worship of the Gods. For Carab signifies to offer in Arabic; so Carabe, an offering: or seizing chaff, as Scaliger quotes from Abohalis, out of the Arabic or Persian language. Some also call it Amber, especially the Indian and Ethiopian amber, called in Latin *Succinum*, as if it were a juice[111]. The Sudavienses or Sudini[112] call it *geniter*, as though it were generated terrestrially. The errors of the ancients concerning its nature and origin having been exploded, it is certain that amber comes for the most part from the sea, and the rustics collect it on the coast after the more violent storms, with nets and other tackle; as among the Sudini of Prussia; and it is also found sometimes

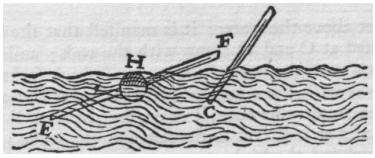
on the coast of our own Britain. It seems, however, to be produced also in the soil and at spots of some depth, like other bitumens; to be washed out by the waves of the sea; and to become concreted more firmly from the nature and saltness of the sea-water. For it was at first a soft and viscous material; wherefore also it contains enclosed and entombed in pieces of it, shining in eternal sepulchres, flies, grubs, gnats, ants; which have all flown or crept or fallen into it when it first flowed forth in a liquid state[113]. The ancients and also more recent writers recall (experience proving the same thing), that amber attracts straws and chaff[114]. The same is also done by jet[115], which is dug out of the earth in Britain, in Germany, and in very many lands, and is a rather hard concretion from black bitumen, and as it were a transformation into stone. There are many modern authors[116] who have written and copied from others about amber and jet[117] attracting chaff, and about other substances generally unknown; with whose labours the shops of {48}
booksellers are crammed. Our own age has produced many books about hidden, abstruse, and occult causes and wonders, in all of which amber and jet are set forth as enticing chaff; but they treat the subject in words alone, without finding any reasons or proofs from experiments, their very statements obscuring the thing in a greater fog, forsooth in a cryptic, marvellous, abstruse, secret, occult, way. Wherefore also such philosophy produces no fruit, because very many philosophers, making no investigation themselves, unsupported by any practical experience, idle and inert, make no progress by their records, and do not see what light they can bring to their theories; but their philosophy rests simply on the use of certain Greek words, or uncommon ones; after the manner of our gossips and barbers nowadays, who make show of certain Latin words to an ignorant populace as the insignia of their craft, and snatch at the popular favour. For it is not
* only amber and jet (as they suppose) which entice small bodies[118]; but Diamond, Sapphire, Carbuncle, Iris gem[119], Opal, Amethyst, Vincentina, and Bristolla (an English gem or spar)[120], Beryl, and Crystal[121] do the same. Similar powers of attraction are seen also to be possessed by glass (especially when clear and lucid), as also by false gems made of glass or Crystal, by glass of antimony, and by many kinds of spars from the mines, and by Belemnites. Sulphur also attracts, and mastick, and hard sealing-wax[122] compounded of lac tinctured of various colours. Rather hard resin entices, as does orpiment[123], but less strongly; with difficulty also and indistinctly under a suitable dry sky[124], Rock salt, muscovy stone, and rock alum. This one may see when the air is sharp and clear and rare in mid-winter, when the emanations from the earth hinder
* electricks less, and the electrick bodies become more firmly indurated; about which hereafter. These substances draw everything, not straws and chaff only[125], but all metals, woods, leaves, stones, earths, even water and oil, and everything which is subject to our senses, or is solid; although some write that amber does not attract anything but chaff and certain twigs; (wherefore Alexander Aphrodiseus falsely declares the question of amber to be inexplicable, because it attracts dry chaff only, and not basil leaves[126]), but these are the utterly false and disgraceful tales of the writers. But in order that you may be able clearly to test how such attraction occurs[127], and what those materials[128] are which thus entice other bodies (for even if bodies incline towards some of these, yet on account of weakness they seem not to be raised by them, but are more easily turned), make yourself a versorium of any metal you like, three or four digits in length, resting rather lightly on its point of support after the manner of a magnetick needle, to one end of which bring up a piece of amber or a smooth and polished gem {49}

which has been gently rubbed; for the versorium turns forthwith. Many things are thereby seen to attract, both those which are formed by nature alone, and those which are by art prepared, fused, and mixed; nor is this so much a singular property of one or two things (as is commonly supposed), but the manifest nature of very many, both of simple substances, remaining merely in their own form, and of compositions, as of hard sealing-wax, & of certain other mixtures besides, made of unctuous stuffs. We must, however, investigate more fully whence that tendency arises, and what those forces be, concerning which a few men have brought forward very little, the crowd of philosophizers nothing at all. By Galen three kinds of attractives in general were recognized in nature: a First class of those substances which attract by their elemental quality, namely, heat; the Second is the class of those which attract by the succession of a vacuum; the Third is the class of those which attract by a property of their whole substance, which are also quoted by Avicenna and others. These classes, however, cannot in any way satisfy us; they neither embrace the causes of amber, jet, and diamond, and of other similar substances (which derive their forces on account of the same virtue); nor of the loadstone, and of all magnetick substances, which obtain their virtue by a very dissimilar and alien influence from them, derived from other sources. Wherefore also it is fitting that we find other causes of the motions, or else we must wander (as
* in darkness), with these men, and in no way reach the goal. Amber truly does not allure by heat, since if warmed by fire and brought near straws, it does not attract them, whether it be tepid, or hot, or glowing, or even when forced into the flame. Cardan (as also Pictorio) reckons that this happens in no different way[129] than with the cupping-glass, by the force of fire. Yet the attracting force of the cupping-glass does not really come from the force of fire. But he had previously said that the dry substance wished to imbibe fatty humour, and therefore it was borne towards it. But these statements are at variance with one another, and also foreign to reason. For if amber had moved towards its food, or if other bodies had inclined towards amber as towards provender, there would have been a diminution of the one which was devoured, just as there would have been a growth of the other which was sated. Then why should an attractive force of fire be looked for in amber? If the attraction existed from heat, why should not very many other bodies also attract, if warmed by fire, by the sun, or by friction? Neither can the attraction be on account of the dissipating of the air, when it takes place in open air (yet Lucretius the poet

adduces this as the reason for magnetical motions). Nor in the cupping-glass can heat or fire attract by feeding on air: in the cupping-glass air, having been exhausted into flame, when it {50}
condenses again and is forced into a narrow space, makes the skin and flesh rise in avoiding a
* vacuum. In the open air warm things cannot attract, not metals even or stones, if they should be strongly incandescent by fire. For a rod of glowing iron, or a flame, or a candle, or a blazing torch, or a live coal, when they are brought near to straws, or to a versorium, do not attract; yet at the same time they manifestly call in the air in succession; because they consume it, as lamps do oil. But concerning heat, how it is reckoned by the crowd of philosophizers, in natural philosophy and in *materia medica* to exert an attraction otherwise than nature allows, to which true attractions are falsely imputed, we will discuss more at length elsewhere, when we shall determine what are the properties of heat and cold. They are very general qualities or kinships of a substance, and yet are not to be assigned as true causes, and, if I may say so, those philosophizers utter some resounding words; but about the thing itself prove nothing in particular. Nor does this attraction accredited to amber arise from any singular quality of the substance or kinship, since by more thorough research we find the same effect in very many other bodies; and all bodies, moreover, of whatever quality, are allured by all those bodies. Similarity also is not the cause; because all things around us placed on this globe of the earth, similar and dissimilar, are allured by amber and bodies of this kind; and on that account no cogent analogy is to be drawn either from similarity or identity of substance. But neither do similars mutually attract one another, as stone stone, flesh flesh, nor aught else outside the class of magneticks and electricks. Fracastorio would have it that "things which mutually attract one another are similars, as being of the same species, either in action or in right subjection. Right subjection is that from which is emitted the emanation which attracts and which in mixtures often lies hidden on account of their lack of form, by reason of which they are often different in act from what they are in potency. Hence it may be that hairs and twigs move towards amber and towards diamond, not because they are hairs, but because either there is shut up in them air or some other principle, which is attracted in the first place, and which bears some relation and analogy to that which attracts of itself; in which diamond and amber agree through a principle common to each." Thus far Fracastorio. Who if he had observed by a large number of experiments that all bodies are drawn to electricks except those which are aglow and aflame, and highly rarefied, would never have given a thought to such things. It is easy for men of acute intellect, apart from experiments and practice, to slip and err. In greater error do they remain sunk who maintain these same substances to be not similar, but to be substances near akin; and hold that on that account a thing moves towards another, its like, by which it is brought to more
perfection. But these are ill-considered views; for towards all electricks all things move[130] {51}
except such as are aflame or are too highly rarefied, as air, which is the universal effluvium of this globe and of the world. Vegetable substances draw moisture by which their shoots are rejoiced and grow; from analogy with that, however, Hippocrates, in his *De Natura Hominis*, Book I., wrongly concluded that the purging of morbid humour took place by the specifick force of the drug. Concerning the action and potency of purgatives we shall speak elsewhere. Wrongly also is attraction inferred in other effects; as in the case of a flagon full of water, when buried in a heap of wheat, although well stoppered, the moisture is drawn out; since this moisture is rather resolved into vapour by the emanation of the fermenting wheat, and the wheat imbibes the freed vapour. Nor do elephants' tusks attract moisture, but drive it into vapour or absorb it. Thus then very many things are said to attract, the reasons for whose energy must be sought from other
* causes. Amber in a fairly large mass allures, if it is polished; in a smaller mass or less pure it seems not to attract without friction. But very many electricks (as precious stones and some other substances) do not attract at all unless rubbed. On the other hand many gems, as well as
* other bodies, are polished, yet do not allure, and by no amount of friction are they aroused; thus the emerald, agate, carnelian, pearls, jasper, chalcedony, alabaster, porphyry, coral, the marbles, touchstone, flint, bloodstone, emery[131], do not acquire any power; nor do bones, or ivory, or the hardest woods, as ebony, nor do cedar, juniper, or cypress; nor do metals, silver, gold, brass, iron, nor any loadstone, though many of them are finely polished and shine. But on the other hand there are some other polished substances of which we have spoken before, toward which, when they have been rubbed, bodies incline. This we shall understand only when we have more closely looked into the prime origin of bodies. It is plain to all, and all admit, that the mass of the earth, or rather the structure and crust of the earth, consists of a twofold material, namely, of fluid and humid matter, and of material of more consistency and dry. From this twofold nature or the more simple compacting of one, various substances take their rise among us, which originate in greater proportion now from the earthy, now from the aqueous nature. Those substances which have received their chief growth from moisture, whether aqueous or fatty, or have taken on their form by a simpler compacting from them, or have been compacted from these same materials in long ages, if they have a sufficiently firm hardness, if rubbed after they have been polished and when they remain bright with the friction—towards those substances everything, if presented to them in the air, turns, if its too heavy weight does not prevent it. For amber has been compacted of moisture, and jet also. Lucid gems are made of water; just as Crystal[132],
which has been concreted from clear water, not always by a very great cold, as some used to {52}
judge, and by very hard frost, but sometimes by a less severe one, the nature of the soil fashioning it, the humour or juices being shut up in definite cavities, in the way in which spars are produced in mines. So clear glass is fused out of sand, and from other substances, which have their origin in humid juices. But the dross of metals, as also metals, stones, rocks, woods, contain
* earth rather, or are mixed with a good deal of earth; and therefore they do not attract. Crystal, mica, glass, and all electricks do not attract if they are burnt or roasted; for their primordial supplies of moisture perish by heat, and are changed and exhaled. All things therefore which

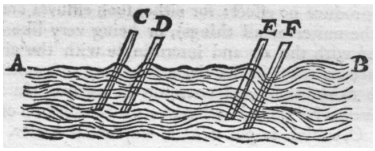
have sprung from a predominant moisture and are firmly concreted, and retain the appearance of spar and its resplendent nature in a firm and compact body, allure all bodies, whether humid or dry. Those, however, which partake of the true earth-substance or are very little different from it, are seen to attract also, but from a far different reason, and (so to say) magnetically; concerning these we intend to speak afterwards. But those substances which are more mixed of water and earth, and are produced by the equal degradation of each element (in which the magnetick force of the earth is deformed and remains buried; while the watery humour, being fouled by joining with a more plentiful supply of earth, has not concreted in itself but is mingled with earthy matter), can in no way of themselves attract or move from its place anything which they do not touch. On this account metals, marbles, flints, woods, herbs, flesh, and very many other things can neither allure nor solicit any body either magnetically or electrically. (For it pleases us to call
* that an electrick force, which hath its origin from the humour.) But substances consisting mostly of humour, and which are not very firmly compacted by nature (whereby do they neither bear rubbing, but either melt down and become soft, or are not levigable, such as pitch, the softer kinds of resin, camphor, galbanum, ammoniack[133], storax, asafœtida, benzoin, asphaltum, especially in rather warm weather) towards them small bodies are not borne; for without rubbing
* most electricks do not emit their peculiar and native exhalation and effluvium. The resin turpentine when liquid does not attract; for it cannot be rubbed; but if it has hardened into a mastick it does attract. But now at length we must understand why small bodies turn towards those substances which have drawn their origin from water; by what force and with what hands (so to speak) electricks seize upon kindred natures. In all bodies in the world two causes or principles have been laid down, from which the bodies themselves were produced, matter and form[134]. Electrical motions become strong from matter, but magnetick from form chiefly; and they differ widely from one another and turn out unlike, since the one is ennobled by numerous virtues and is prepotent; the other is ignoble and of less potency, and mostly restrained, as it {53}
were, within certain barriers; and therefore that force must at times be aroused by attrition or friction, until it is at a dull heat and gives off an effluvium and a polish is induced on the body.
* For spent air, either blown out of the mouth or given off from moister air, chokes the virtue. If indeed either a sheet of paper or a piece of linen be interposed, there will be no movement. But a loadstone, without friction or heat, whether dry or suffused with moisture, as well in air as in water, invites magneticks, even with the most solid bodies interposed, even planks of wood or
* pretty thick slabs of stone or sheets of metal. A loadstone appeals to magneticks only; towards electricks all things move. A loadstone[135] raises great weights; so that if there is a loadstone weighing two ounces and strong, it attracts half an ounce or a whole ounce. An electrical substance only attracts very small weights; as, for instance, a piece of amber of three ounces weight, when rubbed, scarce raises a fourth part of a grain of barley. But this attraction of amber and of electrical substances must be further investigated; and since there is this particular affection of matter, it may be asked why is amber rubbed, and what affection is produced by the rubbing, and what causes arise which make it lay hold on everything? As a result of friction it grows slightly warm and becomes smooth; two results which must often occur together. A large polished fragment of amber or jet attracts indeed, even without friction, but less strongly; but if it be brought gently near a flame or a live coal, so that it equally becomes warm, it does not attract
* small bodies because it is enveloped in a cloud from the body of the flaming substance, which emits a hot breath, and then impinges upon it vapour from a foreign body which for the most part is at variance with the nature of amber. Moreover the spirit of the amber which is called forth is enfeebled by alien heat; wherefore it ought not to have heat excepting that produced by motion only and friction, and, as it were, its own, not sent into it by other bodies. For as the igneous heat emitted from any burning substance cannot be so used that electricks may acquire their force
* from it; so also heat from the solar rays does not fit an electrick by the loosening of its right material, because it dissipates rather and consumes it (albeit a body which has been rubbed retains its virtue longer exposed to the rays of the sun than in the shade; because in the shade the effluvia are condensed to a greater degree and more quickly). Then again the fervour from
* the light of the Sun aroused by means of a burning mirror confers no vigour on the heated
* amber[136]; indeed it dissipates and corrupts all the electrick effluvia. Again, burning sulphur and hard wax, made from shell-lac, when aflame do not allure; for heat from friction resolves bodies into effluvia, which flame consumes away. For it is impossible for solid electricks to be resolved into their own true effluvia otherwise than by attrition, save in the case of certain substances {54}
which by reason of innate vigour emit effluvia constantly. They are rubbed with bodies which do not befoul their surface, and which produce a polish, as pretty stiff silk or a rough wool rag which is as little soiled as possible, or the dry palm. Amber also is rubbed with amber, with diamond, and with glass, and numerous other substances. Thus are electricks manipulated. These things being so, what is it which moves? Is it the body itself, inclosed within its own circumference? Or is it something imperceptible to us, which flows out from the substance into the ambient air? Somewhat as Plutarch opines, saying in his *Quæstiones Platonicæ*[137]: That there is in amber something flammable or something having the nature of breath, and this by the attrition of the surface being emitted from its relaxed pores attracts bodies. And if it be an effusion does it seize upon the air whose motion the bodies follow, or upon the bodies themselves? But if amber allured the body itself, then what need were there of friction, if it is bare and smooth? Nor does the force arise from the light which is reflected from a smooth and polished body; for a Gem of Vincent's rock[138], Diamond, and clear glass, attract when they are rough; but not so powerfully and quickly, because they are not so readily cleansed from extraneous moisture on the surface, and are not rubbed equally so as to be copiously resolved at that part. Nor does the sun by its own beams of light and its rays, which are of capital importance in nature, attract bodies in this way;

and yet the herd of philosophizers considers that humours are attracted by the sun, when it is only denser humours that are being turned into thinner, into spirit and air; and so by the motion of effusion they ascend into the upper regions, or the attenuated exhalations are raised up from the denser air. Nor does it seem to take place from the effluvia attenuating the air, so that bodies impelled by the denser air penetrate towards the source of the rarefaction; in this case both hot and flaming bodies would also allure other bodies; but not even the lightest chaff, or any versorium moves towards a flame. If there is a flow and rush of air towards the body, how can a small diamond of the size of a pea[139] summon towards itself so much air, that it seizes hold of a biggish long body placed in equilibrio (the air about one or other very small part of an end being attracted)? It ought also to have slopped or moved more slowly, before it came into contact with the body, especially if the piece of amber was rather broad and flat, from the accumulation of air on the surface of the amber and its flowing back again. If it is because the effluvia are thinner, and denser vapours come in return, as in breathing, then the body would rather have had a motion toward the electrick a little while after the beginning of the application; but when
* electricks which have been rubbed are applied quickly to a versorium then especially at once they act on the versorium, and it is attracted more when near them. But if it is because the rarefied effluvia produce a rarefied medium, and on that account bodies are more prone to slip {55}
down from a denser to a more attenuated medium; they might have been carried from the side in this way or downwards, but not to bodies above them; or the attraction and apprehension of contiguous bodies would have been momentary only. But with a single friction jet and amber draw and attract bodies to them strongly and for a long time, sometimes for the twelfth part of an hour, especially in clear weather. But if the mass of amber be rather large, and the surface polished, it attracts without friction. Flint is rubbed and emits by attrition an inflammable matter that turns into sparks and heat. Therefore the denser effluvia of flint producing fire are very far different from electrical effluvia, which on account of their extreme attenuation do not take fire, nor are fit material for flame. Those effluvia are not of the nature of breath, for when emitted they do not propel anything, but are exhaled without sensible resistance and touch bodies. They are highly attenuated humours much more subtile than the ambient air; and in order that they may occur, bodies are required produced from humour and concreted with a considerable degree of hardness. Non-electrick bodies are not resolved into humid effluvia, and those effluvia mix with the common and general effluvia of the earth, and are not peculiar. Also besides the attraction of bodies, they retain them longer. It is probable therefore that amber does exhale
* something peculiar to itself, which allures bodies themselves, not the intermediate air. Indeed it plainly does draw the body itself in the case of a spherical drop of water standing on a dry surface; for a piece of amber applied to it at a suitable distance pulls the nearest parts out of
* their position and draws it up into a cone; otherwise, if it were drawn by means of the air rushing along, the whole drop would have moved. That it does not attract the air is thus demonstrated: take a very thin wax candle, which makes a very small and clear flame; bring up to this, within
* two digits or any convenient distance, a piece of amber or jet, a broad flat piece, well prepared and skilfully rubbed, such a piece of amber as would attract bodies far and wide, yet it does not disturb the flame; which of necessity would have occurred, if the air was disturbed, for the flame would have followed the current of air. As far as the effluvia are sent out, so far it allures; but as a body approaches, its motion is accelerated, stronger forces drawing it; as also in the case of magneticks and in all natural motion; not by attenuating or by expelling the air, so that the body moves down into the place of the air which has gone out[140]; for thus it would have allured only and would not have retained; since it would at first also have repelled approaching bodies just as it drives the air itself; but indeed a particle, be it ever so small, does not avoid the first application made very quickly after rubbing. An effluvium exhales from amber and is emitted by rubbing: pearls, carnelian, agate, jasper, chalcedony, coral, metals, and other substances of that {56}
kind, when they are rubbed, produce no effect. Is there not also something which is exhaled from them by heat and attrition? Most truly; but from grosser bodies more blended with the earthy nature, that which is exhaled is gross and spent; for even towards very many electricks, if they
* are rubbed too hard, there is produced but a weak attraction of bodies, or none at all; the attraction is best when the rubbing has been gentle and very quick; for so the finest effluvia are evoked. The effluvia arise from the subtile diffusion of humour, not from excessive and turbulent violence; especially in the case of those substances which have been compacted from unctuous matter, which when the atmosphere is very thin, when the North winds, and amongst us (English) the East winds, are blowing, have a surer and firmer effect, but during South winds and
* in damp weather, only a weak one; so that those substances which attract with difficulty in clear weather, in thick weather produce no motion at all; both because in grosser air lighter substances move with greater difficulty; and especially because the effluvia are stifled, and the surface of the body that has been rubbed is affected by the spent humour of the air, and the effluvia are stopped at their very starting. On that account in the case of amber, jet, and sulphur, because they do not so easily take up moist air on their surface and are much more plenteously set free, that force is not so quickly suppressed as in gems, crystal, glass, and substances of that kind which collect on their surface the moister breath which has grown heavy. But it may be asked why does amber allure water, when water placed on its surface removes its action? Evidently because it is one thing to suppress it at its very start, and quite another to extinguish it
* when it has been emitted. So also thin and very fine silk, in common language *Sarcenet*, placed
* quickly on the amber, after it has been rubbed, hinders the attraction of the body; but if it is interposed in the intervening space, it does not entirely obstruct it. Moisture also from spent air, and any breath blown from the mouth, as well as water put on the amber, immediately
* extinguishes its force. But oil, which is light and pure, does not hinder it; for although amber be
* rubbed with a warm finger dipped in oil, still it attracts. But if that amber, after the rubbing, is

moistened with *aqua vitæ* or spirits of wine, it does not attract; for it is heavier than oil, denser, and when added to oil sinks beneath it. For oil is light and rare, and does not resist the most delicate effluvia. A breath therefore, proceeding from a body which had been compacted from humour or from a watery liquid, reaches the body to be attracted; the body that is reached is united with the attracting body, and the one body lying near the other within the peculiar radius of its effluvia makes one out of two; united, they come together into the closest accord, and this is commonly called attraction. This unity, according to the opinion of Pythagoras, is the principle of {57}
all things, and through participation in it each several thing is said to be one. For since no action can take place by means of matter unless by contact, these electricks are not seen to touch, but, as was necessary, something is sent from the one to the other, something which may touch closely and be the beginning of that incitement. All bodies are united and, as it were, cemented together in some way by moisture; so that a wet body, when it touches another body, attracts it, if it is small. So wet bodies on the surface of water attract wet bodies. But the peculiar electrical effluvia, which are the most subtile material of diffuse humour, entice corpuscles. Air (the common effluvium of the earth) not only unites the disjointed parts, but the earth calls bodies back to itself by means of the intervening air; otherwise bodies which are in higher places would not so eagerly make for the earth. Electrical effluvia differ greatly from air; and as air is the effluvium of the earth, so electricks have their own effluvia and properties, each of them having by reason of its peculiar effluvia a singular tendency toward unity, a motion toward its origin and fount, and toward the body emitting the effluvia. But those substances which by attrition emit a gross or vapourous or aeriform effluvium produce no effect; for either such effluvia are alien to the humour (the uniter of all things), or being very like common air are blended with the air and intermingle with the air, wherefore they produce no effect in the air, and do not cause motions
* different from those so universal and common in nature. In like manner bodies strive to be united and move on the surface of water, just as the rod C, which is put a little way under water. It is plain that the rod E F, which floats on the water by reason of the cork H, and only has its wet end F above the surface of the water, is attracted by the rod C, if the rod C is wet a little above the surface of the water; they are suddenly united, just as a drop adjoining a drop is attracted. So a wet thing on the surface of water seeks union with a wet thing,



since the surface of the water is raised on both; and they immediately flow together, just like drops or bubbles. But they are in much greater proximity than electricks, and are united by their
* clammy natures. If, however, the whole rod be dry above the water, it no longer attracts, but drives away the stick E F. The same is seen in those bubbles also which are made on water. For {58}
we see one drive towards another, and the quicker the nearer they are. Solids are impelled towards solids by the medium of liquid: for example, touch the end of a versorium with the end of a rod on which a drop of water is projecting; as soon as the versorium touches the top of the
* droplet, immediately it is joined strongly by a swift motion to the body of the rod. So concreted humid things attract when a little resolved into air (the effluvia in the intermediate space tending to produce unity); for water has on wet bodies, or on bodies wet with abundant moisture on the top of water, the force of an effluvium. Clear air is a convenient medium for an electrical effluvium excited from concreted humour. Wet bodies projecting above the surface of water (if they are near) run together so that they may unite; for the surface of the water is raised around wet substances. But a dry thing is not impelled to a wet one, nor a wet to a dry, but seems to run away. For if all is dry above the water, the surface of the water close to it does not rise, but shuns it, the wave sinking around a dry thing. So neither does a wet thing move towards the dry rim of a vessel; but it seeks a wet rim. A B is the surface of the water; C D two rods, which stand up wet above the water; it is manifest that the surface of the water is raised at C and D along with the rods; and therefore the rod C, by reason of the water standing up (which seeks its level and unity), moves with the water to D. On E, on the other hand, a wet rod, the water also rises; but on the dry rod F the surface is depressed; and as it drives to depress



also the wave rising on E in its neighbourhood, the higher wave at E turns away from F[141]; for it does not suffer itself to be depressed. All electrical attraction occurs through an intervening humour; so it is by reason of humour that all things mutually come together; fluids indeed and aqueous bodies on the surface of water, but concreted things, if they have been resolved into vapour, in air;—in air indeed, the effluvium of electricks being very rare, that it may the better permeate the medium and not impel it by its motion; for if that effluvium had been thick, as that of air, or of the winds, or of saltpetre burnt by fire, as the thick and foul effluvia given out with very great force, from other bodies, or air set free from humour by heat rushing out through a pipe (in the instrument of Hero of Alexandria, described in his book *Spiritalia*), then the effluvium {59}
would drive everything away, not allure it. But those rarer effluvia take hold of bodies and embrace them as if with arms extended, with the electricks to which they are united; and they are drawn to the source, the effluvia increasing in strength with the proximity. But what is that effluvium from crystal, glass, and diamond, since these are bodies of considerable hardness and firmly concreted? In order that such an effluvium should be produced, there is no need of any marked or perceptible flux[142] of the substance; nor is it necessary that the electrick should be abraded, or worn away, or deformed. Some odoriferous substances are fragrant for many years, exhaling continually, yet are not quickly consumed. Cypress wood as long as it is sound, and it lasts a very long time indeed, is redolent; as many learned men attest from experience. Such an electrick only for a moment, when stimulated by friction, emits powers far more subtile and more fine beyond all odours; yet sometimes amber, jet, sulphur, when they are somewhat easily let free

into vapour, also pour out at the same time an odour; and on this account they allure with the very gentlest rubbing, often even without rubbing; they also excite more strongly, and retain hold for a longer time, because they have stronger effluvia and last longer. But diamond, glass, rock-
* crystal, and numerous others of the harder and firmly concreted gems first grow warm: therefore at first they are rubbed longer, and then they also attract strongly; nor are they otherwise set free into vapour. Everything rushes towards electricks[143] excepting flame, and flaming bodies, and the thinnest air. Just as they do not draw flame, in like manner they do not affect a versorium, if on any side it is very near to a flame, either the flame of a lamp or of any burning
* matter. It is manifest indeed that the effluvia are destroyed by flame and igneous heat; and therefore they attract neither flame nor bodies very near a flame. For electrical effluvia have the virtue of, and are analogous with, extenuated humour; but they will produce their effect, union and continuity, not by the external impulse of vapours, not by heat and attenuation of heated
* bodies, but by their humidity itself attenuated into its own peculiar effluvia. Yet they entice smoke sent out by an extinguished light; and the more that smoke is attenuated in seeking the upper regions, the less strongly is it turned aside; for things that are too rarefied are not drawn
* to them; and at length, when it has now almost vanished, it does not incline towards them at all, which is easily seen against the light. When in fact the smoke has passed into air, it is not moved, as has been demonstrated before. For air itself, if somewhat thin, is not attracted in any way, unless on account of succeeding that which has vacated its place, as in furnaces and such-like, where the air is fed in by mechanical devices for drawing it in. Therefore an effluvium resulting from a non-fouling friction, and one which is not changed by heat, but which is its own, causes {60}
union and coherency, a prehension and a congruence towards its source, if only the body to be attracted is not unfitted for motion, either by the surroundings of the bodies or by its own weight. To the bodies therefore of the electricks themselves small bodies are borne. The effluvia extend out their virtue—effluvia which are proper and peculiar to them, and *sui generis*, differing from common air, being produced from humour, excited by a calorifick motion from attrition and attenuation. And as if they were material rays[144], they hold and take up chaff, straws, and twigs, until they become extinct or vanish away: and then they (the corpuscles) being loosed again, attracted by the earth itself, fall down to the earth. The difference between Magneticks and Electricks[145] is that all magneticks run together with mutual forces; electricks only allure;
* that which is allured is not changed by an implanted force, but that which has moved up to them voluntarily rests upon them by the law of matter. Bodies are borne towards electricks in a straight line towards the centre of the electrick; a loadstone draws a loadstone directly at the poles only, in other parts obliquely and transversely, and in this way also they adhere and hang to one another. Electrical motion is a motion of aggregation of matter; magnetical motion is one of disposition and conformation. The globe of the earth is aggregated and cohæres by itself electrically. The globe of the earth is directed and turned magnetically; at the same time also it both cohæres, and in order that it may be solid, is in its inmost parts cemented together.

CHAP. III.

Opinions of others on Magnetick Coition, *which they call Attraction.*

Discussion having now been made concerning electricks, the causes of magnetick coition must be set forth. We say coition, not attraction[146]. The word attraction unfortunately crept into magnetick philosophy from the ignorance of the ancients; for there seems to be force applied where there is attraction and an imperious violence dominates. For, if ever there is talk about magnetick attraction, we understand thereby magnetick coition, or a primary running together. Now in truth it will not be useless here first briefly to set forth the views given by others, both the ancient and the more modern writers. {61}
Orpheus in his hymns[147] narrates that iron is attracted by loadstone as the bride to the arms of her espoused. Epicurus holds that iron is attracted by a loadstone just as straws by amber; "and," he adds, "the Atoms and indivisible particles which are given off by the stone and by the iron fit one another in shape; so that they easily cling to one another; when therefore these solid particles of stone or of iron strike against one another, then they rebound into space, being brought against one another by the way, and they draw the iron along with them." But this cannot be the case in the least; since solid and very dense substances interposed, even squared blocks of marble, do not obstruct this power, though they can separate atoms from atoms; and the stone and the iron would be speedily dissipated into such profuse and perpetual streams of atoms. In the case of amber, since there is another different method of attracting, the Epicurean atoms cannot fit one another in shape. Thales, as Aristotle writes, *De Anima*, Bk. I., deemed the loadstone to be endowed with a soul of some sort, because it had the power of moving and drawing iron towards it. Anaxagoras also held the same view. In the *Timæus* of Plato there is an idle fancy[148] about the efficacy of the stone of Hercules. For he says that "all flowings of water, likewise the fallings of thunderbolts, and the things which are held wonderful in the attraction of Amber, and of the Herculean stone, are such that in all these there is never any attraction; but since there is no vacuum, the particles drive one another mutually around, and when they are dispersed and congregated together, they all pass, each to its proper seat, but with changed places; and it is forsooth, on account of these intercomplicated affections that the effects seem to

arouse the wonder in him who has rightly investigated them." Galen does not know why Plato should have seen fit to select the theory of circumpulsion rather than that of attraction (differing almost on this point alone from Hippocrates), though indeed it does not agree in reality with either reason or experiment. Nor indeed is either the air or anything else circumpelled; and the bodies themselves which are attracted are carried towards the attracting substance not confusedly, or in an orbe. Lucretius, the poet of the Epicurean sect, sang his opinion of it thus:

[149]*First, then, know,*
Ceaseless effluvia from the magnet flow,—
Effluvia, whose superior powers expel
The air that lies between the stone and steel.
A vacuum formed, the steely atoms fly
In a link'd train, and all the void supply;
While the whole ring to which the train is join'd
The influence owns, and follows close behind. &c.

Such a reason Plutarch also alleges in the *Quæstiones Platonicæ*: That that stone gives off heavy {62}
exhalations, whereby the adjacent air, being impelled along, condenses that which is in front of it; and that air, being driven round in an orbe and reverting to the place it had vacated, drags the iron forcibly along with it. The following explanation of the virtues of the loadstone and of amber is propounded by Johannes Costæus of Lodi[150]. For he would have it that "there is mutual work and mutual result, and therefore the motion is partly due to the attraction of the loadstone and partly to a spontaneous movement on the part of the iron: For as we say that vapours issuing from the loadstone hasten by their own nature to attract the iron, so also the air repelled by the vapours, whilst seeking a place for itself, is turned back, and when turned back, it impels the iron, lifts it up, as it were, and carries it along; the iron being of itself also excited somehow. So by being drawn out and by a spontaneous motion, and by striking against another substance, there is in some way produced a composite motion, which motion would nevertheless be rightly referred to attraction, because the terminus from which this motion invariably begins is the same terminus at which it ends, which is the characteristic proper of an attraction." There is certainly a mutual action, not an operation, nor does the loadstone attract in that way; nor is there any impulsion. But neither is there that origination of the motion by the vapours, and the turning of them back, which opinion of Epicurus has so often been quoted by others. Galen errs in his *De Naturalibus Facultatibus*, Book I., chap. 14, when he expresses the view that whatever agents draw out either the venom of serpents or darts also exhibit the same power as the loadstone. Now of what sort may be the attraction of such medicaments (if indeed it may be called attraction) we shall consider elsewhere. Drugs against poisons or darts have no relation to, no similitude with, the action of magnetical bodies. The followers of Galen (who hold that purgative medicaments attract because of similitude of substance) say that bodies are attracted on account of similitude, not identity, of substance; wherefore the loadstone draws iron, but iron does not draw iron. But we declare and prove that this happens in primary bodies, and in those bodies that are pretty closely related to them and especially like in kind one to another, on account of their identity; wherefore also loadstone draws loadstone and likewise iron iron; every really true earth draws earth; and iron fortified by a loadstone within the orbe of whose virtue it is placed draws iron more strongly than it does the loadstone. Cardan asks why no other metal is attracted by any other stone; because (he replies) no metal is so cold as iron; as if indeed cold were the cause of the attraction, or as if iron were much colder than lead, which neither follows nor is deflected towards a loadstone. But that is a chilly story, and worse than an old woman's tale. So also is the {63}
notion that the loadstone is alive and that iron is its food. But how does the loadstone feed on the iron, when the filings in which it is kept are neither consumed nor become lighter? Cornelius Gemma, *Cosmographia*, Bk. X.[151], holds that the loadstone draws iron to it by insensible rays, to which opinion he conjoins a story of a sucking fish and another about an antelope. Guilielmus Puteanus[152] derives it, "not from any property of the whole substance unknown to any one and which cannot be demonstrated in any way (as Galen, and after him almost all the physicians, have asserted), but from the essential nature of the thing itself, as if moving from the first by itself, and, as it were, by its own most powerful nature and from that innate temperament, as it were an instrument, which its substance, its effective nature uses in its operations, or a secondary cause and deprived of its intermediary"; so the loadstone attracts the iron not without a physical cause and for the sake of some good. But there is no such thing in other substances springing from some material form; unless it were primary, which he does not recognize. But certes good is shown to the loadstone by the stroke of the iron (as it were, association with a friend); yet it cannot either be discovered or conceived how that disposition may be the instrument of form. For what can temperament do in magnetical motions, which must be compared with the fixed, definite, constant motions of the stars, at great distances in case of the interposition of very dense and thick bodies? To Baptista Porta[153] the loadstone seems a sort of mixture of stone and iron, in such a way that it is an iron stone or stony iron. "But I think" (he says) "the Loadstone is a mixture of stone and iron, as an iron stone, or a stone of iron. Yet do not think the stone is so changed into iron, as to lose its own Nature, nor that the iron is so drowned in the stone, but it preserves itself; and whilst one labours to get the victory of the other, the attraction is made by the combat between them. In that body there is more of the stone than of iron; and therefore the iron, that it may not be subdued by the stone, desires the force and company of iron; that being not able to resist alone, it may be able by more help to defend itself.... The Loadstone draws not stones, because it wants them not, for there is stone enough in the body of it; and if one Loadstone draw another, it is not for the stone, but for the iron that is in

it." As if in the loadstone the iron were a distinct body and not mixed up as the other metals in their ores! And that these, being so mixed up, should fight with one another, and should extend their quarrel, and that in consequence of the battle auxiliary forces should be called in, is indeed absurd. But iron itself, when excited by a loadstone, seizes iron no less strongly than the loadstone. Therefore those fights, seditions, and conspiracies in the stone, as if it were nursing up perpetual quarrels, whence it might seek auxiliary forces, are the ravings of a babbling old {64} woman, not the inventions of a distinguished mage. Others have lit upon sympathy as the cause. There may be fellow-feeling, and yet the cause is not fellow-feeling; for no passion can rightly be said to be an efficient cause. Others hold likeness of substance, many others insensible rays as the cause; men who also in very many cases often wretchedly misuse rays, which were first introduced in the natural sciences by the mathematicians. More eruditely does Scaliger[154] say that the iron moves toward the loadstone as if toward its parent, by whose secret principles it may be perfected, just as the earth toward its centre. The Divine Thomas[155] does not differ much from him, when in the 7th book of his *Physica* he discusses the reasons of motions. "In another way," he says, "it may be said to attract a thing, because it moves it to itself by altering it in some way, from which alteration it happens that when altered it moves according to its position, and in this manner the loadstone is said to attract iron. For as the parent moves things whether heavy or light, in as far as it gives them a form, by means of which they are moved to their place; so also the loadstone gives a certain quality to the iron, in accordance with which it moves towards it." This by no means ill-conceived opinion this most learned man shortly afterwards endeavoured to confirm by things which had obtained little credence respecting the loadstone and the adverse forces of garlick. Cardinal Cusan[156] also is not to be despised. "Iron has," he says, "in the loadstone a certain principle of its own effluence; and whilst the loadstone by its own presence excites the heavy and ponderous iron, the iron is borne by a wonderful yearning, even above the motion of nature (by which in accordance with its weight it ought to tend downwards) and moves upwards, in uniting itself with its own principle. For if there were not in the iron a certain natural foretaste of the loadstone itself, it would not move to the loadstone any more than to any other stone; and unless there were in the stone a greater inclination for iron than for copper, there would not be that attraction." Such are the opinions expressed about the loadstone attracting (or the general sense of each), all dubious and untrustworthy. But those causes of the magnetical motions, which in the schools of the Philosophers are referred to the four elements and the prime qualities, we relinquish to the moths and the worms.

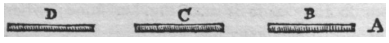
CHAP. IIII. {65}

On Magnetick Force & Form, what it is; and on the *cause of the Coition.*

Relinquishing the opinions of others on the attraction of loadstone, we shall now show the reason of that coition and the translatory nature of that motion. Since there are really two kinds of bodies, which seem to allure bodies with motions manifest to our senses, Electricks and Magneticks, the Electricks produce the tendency by natural effluvia from humour; the Magneticks by agencies due to form, or rather by the prime forces. This form is unique, and particular, not the formal cause of the Peripateticks, or the specifick in mixtures, or the secondary form; not the propagator of generating bodies, but the form of the primary and chief spheres and of those parts of them which are homogeneous and not corrupted, a special entity and existence, which we may call a primary and radical and astral form; not the primary form of Aristotle, but that unique form, which preserves and disposes its own proper sphere. There is one such in each several globe, in the Sun, the moon, and the stars; one also in the earth, which is that true magnetick potency which we call the primary vigour. Wherefore there is a magnetick nature peculiar to the earth and implanted in all its truer parts in a primary and astonishing manner; this is neither derived nor produced from the whole heaven by sympathy or influence or more occult qualities, nor from any particular star; for there is in the earth a magnetick vigour of its own, just as in the sun and moon there are forms of their own, and a small portion of the moon settles itself in moon-manner toward its termini and form; and a piece of the sun to the sun, just as a loadstone to the earth and to a second loadstone by inclining itself and alluring in accordance with its nature. We must consider therefore about the earth what magnetical bodies are, and what is a magnet; then also about the truer parts of it, which are magnetical, and how they are affected as a result of the coition. A body which is attracted by an electrick is not changed by it, but remains unshaken and unchanged, as it was before, nor does it excel any the more in virtue. A loadstone draws magnetical substances, which eagerly acquire
* power from its strength, not in their extremities only, but in their inward parts and their very marrow. For when a rod of iron is laid hold of, it is magnetically excited in the end by which it is laid hold of, and that force penetrates even to the other extremity, not through its surface only, {66} but through the interior and all through the middle. Electrical bodies have material and corporeal effluvia. Is any such magnetical effluvium given off, whether corporeal or incorporeal? or is nothing at all given off that subsists? If it really has a body, that body must be thin and spiritual, since it is necessary that it should be able to enter into iron. Or what sort of an exhalation is it that comes from lead, when quicksilver which is bright and fluid is bound together by the odour merely and vapour of the lead, and remains, as it were, a firm metal? But even gold, which is

exceedingly solid and dense, is reduced to a powder by the thin vapour of lead. Or, seeing that, as the quicksilver has entrance into gold, so the magnetical odour has entrance into the substance of the iron, how does it change it in its essential property, although no change is perceptible to our senses in the bodies themselves? For without ingression into the body, the body is not changed, as the Chemists not incorrectly teach. But if indeed these things resulted from a material ingression, then if strong and dense and thick substances had been interposed between the bodies, or if magnetical substances had been inclosed in the centres of the most solid and the densest bodies, the iron particles would not have suffered anything from the loadstone. But none the less they strive to come together and are changed. Therefore there is no such conception and origin of the magnetick powers; nor do the very minute portions of the stone exist, which have been wrongly imagined to exist by Baptista Porta, aggregated, as it were, into hairs, and arising from the rubbing of the stone which, sticking to the iron, constitute its strength. Electrick effluvia are not only impeded by any dense matter, but also in like manner by flames, or if a small flame is near, they do not allure. But as iron is not hindered by any obstacle from receiving force or motion from a loadstone, so it will pass through the midst of flames to the body of the loadstone and adhære to the stone. Let there be a flame or a candle near the stone; bring up a short piece of iron wire, and when it has come near, it will penetrate through the
* midst of the flames to the stone; and a versorium turns towards the loadstone nor more slowly nor less eagerly through the midst of flames than through open air. So flames interposed do not hinder the coition. But if the iron itself became heated by a great heat, it is demonstrable that it would not be attracted. Bring a strongly ignited rod of iron near a magnetized versorium; the
* versorium remains steady and does not turn towards such iron; but it immediately turns towards it, so soon as it has lost somewhat of its heat. When a piece of iron has been touched by a
* loadstone, if it be placed in a hot fire until it is perfectly red hot and remain in the fire some considerable time, it will lose that magnetick strength it had acquired. Even a loadstone itself through a longish stay in the fire, loses the powers of attracting implanted and innate in it, and {67}
any other magnetick powers. And although certain veins of loadstone exhale when burnt a dark vapour of a black colour, or of a sulphurous foul odour, yet that vapour was not the soul, or the cause of its attraction of iron (as Porta thinks), nor do all loadstones whilst they are being baked or burnt smell of or exhale sulphur. It is acquired as a sort of inborn defect from a rather impure mine or matrix. Nor does anything analogous penetrate into the iron from that material corporeal cause, since the iron conceives the power of attracting and verticity from the loadstone, even if glass or gold or any other stone be interposed. Then also cast iron acquires the power of attracting iron, and verticity, from the verticity of the earth, as we shall afterwards plainly demonstrate in *Direction*. But fire destroys the magnetick virtues in a stone, not because it takes away any parts specially attractive, but because the consuming force of the flame mars by the demolition of the material the form of the whole; as in the human body the primary faculties of the soul are not burnt, but the charred body remains without faculties. The iron indeed may remain after the burning is completed and is not changed into ash or slag; nevertheless (as Cardan not inaptly says) burnt iron is not iron, but something placed outside its nature until it is reduced. For just as by the rigour of the surrounding air[157] water is changed from its nature into ice; so iron, glowing in fire, is destroyed by the violent heat, and has its nature confused and perturbed; wherefore also it is not attracted by a loadstone, and even loses that power of attracting in whatever way acquired, and acquires another verticity when, being, as it were, born again, it is impregnated by a loadstone or the earth, or when its form is revived, not having been dead but confused, concerning which many things are manifest in the change of verticity. Wherefore Fracastorio[158] does not confirm his opinion, that the iron is not altered; "for if it were altered," he says, "by the form of the loadstone, the form of the iron would have been spoiled." This alteration is not generation, but the restitution and reformation of a confused form. There is not therefore anything corporeal which comes from the loadstone or which enters the iron, or which is sent back from the iron when it is stimulated; but loadstone disposes loadstone by its primary form; iron, however, which is closely related to it, loadstone at the same time recalls to its conformate strength, and settles it; on account of which it rushes to the loadstone and eagerly conforms itself to it (the forces of each in harmony bringing them together). The coition also is not vague or confused, not a violent inclination of body to body, no rash and mad congruency; no violence is here applied to the bodies; there are no strifes or discords; but there is that concord (without which the universe would go to pieces), that analogy, namely, of the perfect and homogeneous parts of the spheres of the universe to the whole, and a mutual {68}
concurrency of the principal forces in them, tending to soundness, continuity, position, direction, and to unity. Wherefore in the case of such wonderful action and such a stupendous implanted vigour (diverse from other natures) the opinion of Thales of Miletus[159] was not very absurd, nor was it downright madness, in the judgment of Scaliger, for him to grant the loadstone a soul; for the loadstone is incited, directed, and orbitally moved by this force, which is all in all, and, as will be made clear afterwards, all in every part; and it seems to be very like a soul. For the power of moving itself seems to point to a soul; and the supernal bodies, which are also celestial, divine, as it were, are thought by some to be animated, because they move with admirable order. If two loadstones be set one over against the other, each in a boat, on the surface of water, they do not immediately run together, but first they turn towards one another, or the lesser conforms to the greater, by moving itself in a somewhat circular manner, and at length, when they are disposed according to their nature, they run together. In smelted iron which has not been excited by a magnet there is no need for such an apparatus; since it has no verticity, excepting what is adventitious and acquired, and that not stable and confirmed (as is the case with loadstone, even if the iron has been smelted from the best loadstone), on account of the confusion of the parts by fire when it flowed as a liquid; it suddenly acquires polarity and natural aptitude by the presence

of the loadstone, by a powerful mutation, and by a conversion into a perfect magnet, and by an absolute metamorphosis; and it flies to the body of the magnet as if it were a real piece of loadstone. For a loadstone has no power, nor can a perfect loadstone do anything which iron when excited by loadstone cannot perform, even when it has not been touched but only placed in its vicinity. For when first it is within the orbe of virtue of the loadstone, though it may be some distance away, yet it is immediately changed, and has a renovated form, formerly indeed dormant and inert in body, now lively and strong, which will be clearly apparent in the demonstrations of *Direction*. So the magnetick coition is a motion of the loadstone and of the iron, not an action of one[160]; an ἐντελέχεια, of each, not ἔργον; a συνεντελέχεια or conjoint action, rather than a sympathy. There is properly no such thing as magnetick antipathy. For the flight and declination of the ends, or an entire turning about, is an action of each towards unity by the conjoint action and συνεντελέχεια of both. It has therefore newly put on the form, and on account of this being roused, it then, in order that it may more surely acquire it, rushes headlong on the loadstone, not with curves and turnings, as a loadstone to a loadstone. For since in a loadstone both verticity and the power disponent have existed through many ages, or from the very beginnings, have {69}
been inborn and confirmed, and also the special form of the terrestrial globe cannot easily be changed by another loadstone, as iron is changed; it happens from the constant nature of each, that one has not the sudden power over another of changing its verticity, but that they can only
* mutually come to agreement with each other. Again, iron which has been excited by a loadstone, if that iron on account of obstacles should not be able to turn round immediately in accordance with its nature, as happens with a versorium, is laid hold of, when a loadstone approaches, on either side or at either end. Because, just as it can implant, so it can suddenly change the polarity and turn about the formal energies to any part whatever. So variously can iron be transformed when its form is adventitious and has not yet been long resident in the metal. In the case of iron, on account of the fusion of the substance when magnetick ore or iron is smelted, the virtue of its primary form, distinct before, is now confused; but an entire loadstone placed near it again sets up its primal activity; its adjusted and arranged form joins its allied strength with the loadstone; and both mutually agree and are leagued together magnetically in all their motions towards unity, and whether joined by bodily contact or adjusted within the orbe, they are one and the same. For when iron is smelted out of its own ore, or steel (the more noble kind of iron) out of its ore, that is, out of loadstone, the material is loosed by the force of the fire, and flows away, and iron as well as steel flow out from their dross and are separated from it; and the dross is either spoiled by the force of the fire and rendered useless, or is a kind of dregs of a certain imperfection and of mixture in the prominent parts of the earth. The material therefore is a purified one, in which the metallick parts, which are now mixed up by the melting, since those special forces of its form are confused and uncertain, by the approach of a loadstone are called back to life, as if to a kind of disponent form and integrity. The material is thus awakened and moves together into unity, the bond of the universe and the essential for its conservation. On this account and by the purging of the material into a cleaner body, the loadstone gives to the iron a
* greater force of attracting than there is in itself. For if iron dust or an iron nail be placed over a large loadstone, a piece of iron joined to it takes away the filings and nail from the loadstone and retains them so long as it is near the loadstone; wherefore iron attracts iron more than loadstone does, if it have been conformed by a loadstone and remains within the orbe of its communicated form. A piece of iron even, skilfully placed near the pole of a loadstone, lifts up more than the loadstone. Therefore the material of its own ore is better, and by the force of fire steel and iron are re-purged; and they are again impregnated by the loadstone with its own forms; therefore they move towards it by a spontaneous approach as soon as they have entered within the orbe of {70}
the magnetick forces, because they were possessed by it before, connected and united with it in a perfect union; & they have immediately an absolute continuity within that orbe, & have been joined on account of their harmony, though their bodies may have been disjoined. For the iron is not taken possession of and allured by material effluvia, after the manner of electricks, but only by the immaterial action of its form or an incorporeal progression, which in a piece of iron as its subject acts and is conceived, as it were, in a continuous homogeneous body, and does not need more open ways. Therefore (though the most solid substances be interposed) the iron is still moved and attracted, and by the presence of loadstone the iron moves and attracts the loadstone itself, and by mutual forces a concurrency is made towards unity, which is commonly called attraction of the iron. But those formal forces pass out and are united to one another by meeting together; a force also, when conceived in the iron, begins to flow out without delay. But Julius Scaliger, who by other examples contends that this theory is absurd, makes in his 344th Exercise a great mistake. For the virtues of primary bodies are not to be compared with bodies formed from and mixed with them. He would now have been able (had he been still alive) to discern the nature of effused forms in the chapter on forms effused by spherical magneticks. But if iron is injured somewhat by rust, it is affected either only slightly or not at all by the stone. For the metal is spoiled when eaten away and deformed by external injuries or by lapse of time (just as has been said about the loadstone), and it loses its prime qualities which are conjoined to its form; or, being worn out by age, retains them in a languid and weak condition; indeed it cannot be properly re-formed, when it has been corrupted. But a powerful and fresh loadstone attracts sound and clean pieces of iron, and those pieces of iron (when they have conceived strength) have a powerful attraction for other iron wires and iron nails, not only one at a time, but even successively one behind another, three, four or five, end to end, sticking and hanging in order like a chain. The loadstone, however, would not attract the last one following in such a row, if there were no nails between. A loadstone placed as at A draws a nail or a bar B; similarly behind B it draws C; and after C, D. But the nails B and C being removed, the loadstone A, if it

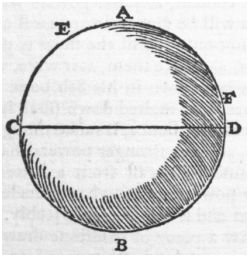


remain at the same distance, does not raise the nail D into the air. This occurs for this reason: because in the case of a continuous row of nails the presence of the loadstone A, besides its own powers, raises the magnetick natures of the iron works B and C, and makes them, as it were, forces auxiliary to itself. But B and C, like a continuous magnetical body, extend as far as D the {71} forces by which D is taken and conformed, though they are weaker than those which C receives from B. And those iron nails indeed from that contact only, and from the presence of the loadstone even without contact, acquire powers which they retain in their own bodies, as will be demonstrated most clearly in the passage *on Direction*. For not only whilst the stone is present does the iron assume these powers, and take them, as it were, vicariously from the stone, as Themistius lays down in his 8th book on Physicks[161]. The best iron, when it has been melted down (such is steel), is allured by a loadstone from a greater distance, is raised though of greater weight, is held more firmly, assumes stronger powers than the common and less expensive, because it is cast from a better ore or loadstone, imbued with better powers. But what is made from more impure ore turns out weaker and is moved more feebly. As to Fracastorio's[162] statement that he saw a piece of loadstone draw a loadstone by one of its faces, but not iron; by another face iron, but not loadstone; by another both; which he says is an indication that in one part there is more of the loadstone, in another more of the iron, in another both equally, whence arises that diversity of attraction; it is most incorrect and badly observed on the part of Fracastorio, who did not know how to apply skilfully loadstone to loadstone. A loadstone draws iron and also a loadstone, if both are suitably arranged and free and unrestrained. That is removed more quickly from its position and place which is lighter; for the heavier bodies are in weight, the more they resist; but the lighter both moves itself to meet the heavier and is allured by the other.

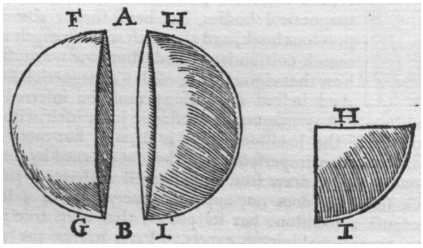
CHAP. V.

How the Power dwells in the *Loadstone*.

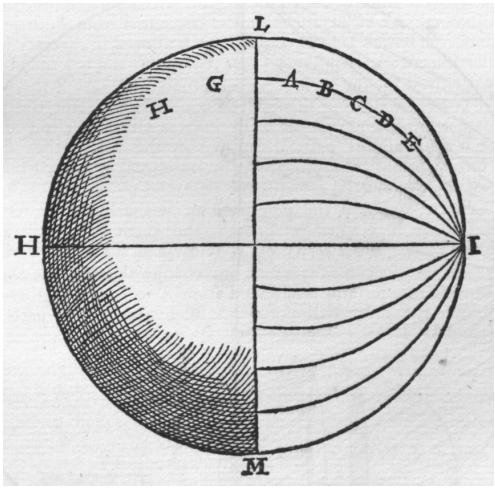
hat a loadstone attracts loadstone, iron and other magnetical bodies, has been shown above in the previous book, and also with what strength the magnetick coition is ordered; but now we must inquire how that vigour is disposed in a magnetick substance. And indeed an analogy must be inferred from a large loadstone. Any magnetick substance joins itself with a loadstone strongly, if the loadstone itself is strong; but more weakly, when it is somewhat imperfect or has been weakened by some flaw. A loadstone does not draw iron equally well with every part; or a magnetick substance does not approach every part of a loadstone alike; because a loadstone has its points, that is its true poles, in which an exceptional virtue excels. Parts nearer the pole are stronger, those far away more {72} weak, and yet in all the power is in a certain way equal. The poles of a terrella are A, B; the æquinoctial is C, D. At A and B the alluring force seems greatest.



At C and D there is no force alluring magnetick ends to the body, for the forces tend toward both poles. But direction is powerful on the æquator. At C, D, the distances are equal from both poles; therefore iron which is at C, D, when it is allured in contrary ways, does not adhære with constancy; but it remains and is joined to the stone, if only it incline to the one or other side. At E there is a greater power of alluring than at F, because E is nearer the pole. This is not so because there is really greater virtue residing at the pole, but since all the parts are united in the whole, they direct their forces towards the pole. From the forces flowing from the plane of the æquinoctial towards the pole, the power increases. A fixed verticity exists at the pole, so long as
* the loadstone remains whole; if it is divided or broken, the verticity obtains other positions in the parts into which it is divided. For the verticity always changes in consequence of any change in the mass, and for this cause, if the terrella be divided from A to B, so that there are two stones, the poles will not be A, B, in the divided parts, but F, G, and H, I.

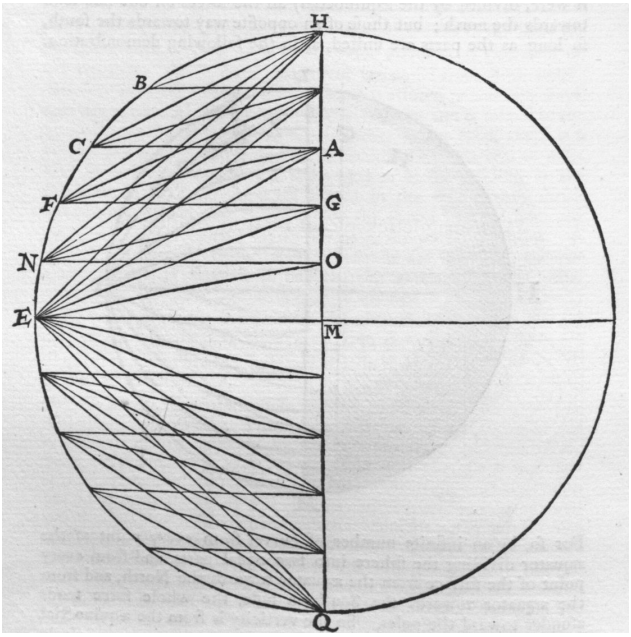


Although these stones now are in agreement with one another, so that F would not seek H, yet if A was previously the boreal pole[163], F is now boreal, and H also boreal; for the verticity is not changed (as Baptista Porta incorrectly affirms in the fourth chapter of his seventh book); since, though F and H do not agree, so that the one would incline to the other, yet both turn to the same point of the horizon. If the hemisphere H I be divided into two quadrants, the one pole takes up its position in H, the other in I. The whole mass of the stone, as I have said, retains the site of its vertex constant; and any part of the stone, before it was cut out from the block[164], might have been the pole or vertex. But concerning this more under *Direction*. It is important now to comprehend and to keep firmly in mind that the vertices are strong on account of the force of the whole, so that (the command being, as it were, divided by the æquinoctial) all the forces on one side tend towards the north; but those of an opposite way towards the south, so long as the parts are united, as in the following demonstration. {73}



For so, by an infinite number of curves from every point of the equator dividing the sphere into two equal parts, and from every point of the surface from the æquator towards the North, and from the æquator towards the Southern pole, the whole force tends asunder toward the poles. So the verticity is from the æquinoctial circle towards the pole in each direction. Such is the power reposed in the undivided stone. From A vigour is sent to B, from A, B, to C, from A, B, C, to D, and from them likewise to E. In like manner from G to H, and so forth, as long as the whole is united. But if a piece A B be cut out (although it is near the æquator), yet it will be as strong in its magnetical actions as C D or D E, if torn away from the whole in equal quantity. For no part excels in special worth in the whole mass except by what is owing to the other adjoining parts by which an absolute and perfect whole is attained. {74}

Diagram of Magnetic Vigour
transmitted from the plane of the Æquator
to the peripherery of the terella
or of the earth



HEQ is a terrella, E a pole, M the centre, HMQ the æquinoctial plane. From every point of the æquinoctial plane vigour extends to the periphery, but by various methods; for from A the formal force is transmitted towards C, F, N, E, and to every point from C up to E, the pole; but not towards B; so neither from G towards C. The power of alluring is not strengthened in the part FHG from that which is in GMFE, but FGH increases the force in the eminence FE. So no force rises from the internal parts, from the lines parallel to the Axis above those parallels, but always inwards from the parallels to the pole. From every point of the plane of the equator force proceeds to the pole E, but the point F has its powers only from GH, and N from OH; but the pole E is strengthened from the whole plane HQ. Wherefore in it the mighty power excels (just as in a palace); but in the intermediate intervals (as in F) only so much force of alluring is exerted as the portion HG of the plane can contribute. {75}

CHAP. VI.

How magnetick pieces of Iron and smaller *loadstones conform themselves to a terrella & to* the earth itself, and by them are *disposed.*

Coition of those bodies which are divided, and do not naturally cohære, if they are free, occurs through another kind of motion. A terrella sends out in an orbe its powers in proportion to its vigour and quality. But when iron or any other magnetick of convenient magnitude comes within its orbe of virtue, it is allured; but the nearer it comes to the body, the more quickly it runs up to it. They move towards the magnet, * not as to a centre, nor towards its centre. For they only do this in the case of the poles themselves, when namely that which is being allured, and the pole of the loadstone, and its centre, are in the same straight line. But in the intervening spaces they tend obliquely, just as is evident in the following figure, in which it is shown how the influence is extended to the adjoining magneticks within the orbe; in the case of the poles straight out.

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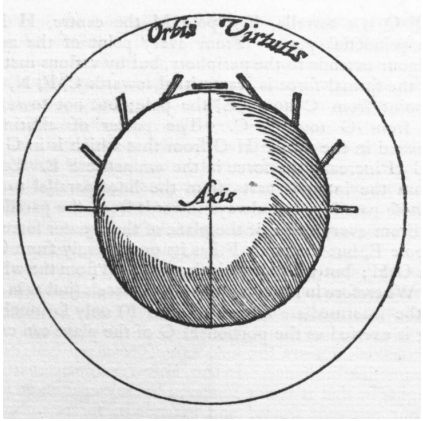


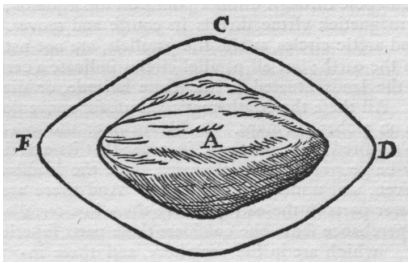
The nearer the parts are to the æquinoctial, the more obliquely are magneticals allured; but the

parts nearer the poles appeal more directly, at the poles quite straight. The principle of the turning of all loadstones, of those which are round and those which are long, is the same, but in the case of the long ones the experiment is easier. For in whatever form they are the verticity exists, and there are poles; but on account of bad and unequal form, they are often hindered by certain evils. If the stone were long, the vertex is at the ends, not on the sides; it allures more strongly at the vertex. For the parts bring together stronger forces to the pole in right lines than oblique. So the stone and the earth conform their magnetick motions by their nature.

CHAP. VII.

On the Potency of the Magnetick Virtue, and on its nature capable of spreading out into an orbe.

From about a magnetical body the virtue magnetical is poured out on every side around in an orbe; around a terrella; in the case of other shapes of stones, more confusedly and unevenly. But yet there exists in nature no orbe or permanent or essential virtue spread through the air, but a magnet only excites magneticks at a convenient distance from it. And as light comes in an instant (as the opticians teach), so much more[165] quickly is the magnetick vigour present within the limits of its strength; and because its activity is much more subtile than light, and does not consent with a non-magnetick substance, it has no intercourse with air, water, or any non-magnetick; nor does it move a magnetick with any motion by forces rushing upon it, but being present in an instant, it invites friendly bodies. And as light strikes an object, so a loadstone strikes a magnetick body and excites it. And just as light does not remain in the air above vapours and effluvia, and is not reflected from those spaces, so neither is the magnetick ray held in air or water. The appearances of things are apprehended in an instant in mirrors and in the eye by means of light; so the magnetick virtue seizes upon magneticks. Without the more intangible and shining bodies, the appearances of things are not seized or reflected; so without magnetical objects the magnetick power is not perceived, nor are the forces thus conceived sent back again to the magnetick substance. In this, however, the magnetick power excels light, in that it is not hindered by any opaque or solid substance, but proceeds freely, and extends its forces on every side. In a terrella and globe-shaped loadstone the magnetick power is extended outside the body in an orbe; in a longer one, however, not in an orbe, but it is extended in an ambit conformably to the shape of the stone. As in the somewhat long stone A, the vigour is extended to the ambient limit F C D, equidistant on every side from the stone A. {77}



CHAP. VIII. {78}

On the geography of the Earth, *and of the Terrella*.

Desiring that what follows may be better understood, we must now say something also about magnetick circles and limits. Astronomers, in order to understand and observe methodically the motion of the planets and the revolution of the heavens, and to describe with more accuracy the celestial attire of the fixed stars, settled upon certain circles and definite limits in the sky (which geographers also imitate), so that the varied face of the earth and the beauty of its districts might be delineated. But we, in a way differing from them, recognize those limits and circles, and have found very many fixed by nature, not merely conceived by the imagination, both in the earth and in our terrella. The earth they mark out[166] chiefly by means of the æquator and the poles; and those limits indeed have been arranged and marked out by nature. The meridians also indicate straight paths from pole to pole through distinct points on the æquator; by which way the magnetick virtue directs its course and moves. But the tropics and arctic circles, as also the parallels, are not natural limits placed on the earth; but all parallel circles indicate a certain agreement of the lands situated in the same latitude, or diametrically opposite. All these the Mathematicians use for convenience, painting them on globes and maps. In like manner also in a terrella all these are required; not, however, in order that its exterior appearance may be geographically delineated, since the loadstone may be

perfect, even, and uniform on all sides. And there are no upper and lower parts in the earth, nor are there in a terrella; unless perchance some one considers those parts superior which are in the periphery, and those inferior which are situated more towards the centre.

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CHAP. IX.

On the Æquinoctial Circle of the Earth *and of a Terrella*.

As conceived by astronomers the æquinoctial circle is equidistant from both poles, cutting the world in the middle, measures the motions of their *primum mobile* or tenth sphere, and is named the zone of the *primum mobile*. It is called æquinoctial, because when the sun stands in it (which must happen twice in the year) the days are equal to the nights. That circle is also spoken of as *æquidialis*, wherefore it is called by the Greeks ἰσημερινός. In like manner it is also properly called Æquator, because it divides the whole frame of the earth between the poles into equal parts. So also an æquator may be rightly assigned to a terrella, by which its power is naturally divided, and by the plane of which permeating through its centre, the whole globe is divided into equal parts both in quantity and strength (as if by a transverse septum) between verticities on both sides imbued with equal vigour.

CHAP. X.

Magnetick Meridians of the Earth.

Meridians have been thought out by the geographer, by means of which he might both distinguish the longitude and measure the latitude of each region. But the magnetick meridians are infinite, running in the same direction also, through fixed and opposite limits on the æquator, and through the poles themselves. On them also the magnetick latitude is measured, and declinations are reckoned from them; and the fixed direction in them tends to the poles, unless it varies from some defect and the magnetick is disturbed from the right way. What is commonly called a magnetick meridian is not really magnetick, nor is it really a meridian, but it is understood to pass through the termini of the variation on the horizon. The variation is a depraved deviation from a meridian, nor is it fixed and constant in various places on any meridian.

{80}

CHAP. XI.

Parallels.

In parallel circles the same strength and equal power are perceived everywhere, when various magneticks are placed on one and the same parallel either on the earth or on a terrella. For they are distant from the poles by equal intervals and have equal tendencies of declination, and they are attracted and held, and they come together with like forces; just as those regions which are situated under the same parallel, even if they differ in longitude, yet we say possess the same quantity of daylight and a climate equally tempered.

CHAP. XII.

The Magnetick Horizon.

Horizon is the name given to the great circle, separating the things which are seen from those which are not seen; so that a half part of the heaven always is open and easily seen by us, half is always hidden. This seems so to us on account of the great distance of the star-bearing orbe: yet the difference is as great as may arise from the ratio of the semi-diameter of the earth compared with the semi-diameter of the starry heaven, which difference is in fact not perceived by our senses. We maintain, however, that the magnetick horizon is a plane level throughout touching the earth or a terrella in the place of some one region, with which plane the semi-diameter, whether of the earth or of the terrella, produced to the place of the region, makes right angles on every side. Such a plane is to be considered in the earth itself and also in the terrella, for magnetick proofs and demonstrations. For we consider the bodies themselves only, not the general appearances of the world. Therefore not with the idea of outlook (which varies with the elevations of the lands), but taking it as a

plane which makes equal angles with the perpendicular, we accept in magnetick demonstrations a sensible horizon or boundary, not that which is called by Astronomers the rational horizon.

CHAP. XIII.

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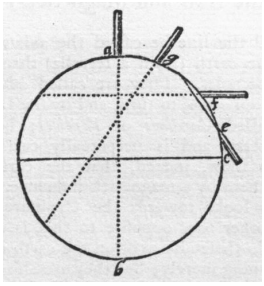
On the Axis and Magnetick Poles.

Let the line be called the axis which is drawn in the earth (as in a terrella) through the centre to the poles. They are called πόλοι by the Greeks from πολεῖν, to turn, and by the Latins they are also called *Cardines* or *Vertices*; because the world rotates and is perpetually carried around them. We are about to show, indeed, that the earth and a terrella are turned about them by a magnetick influence. One of them in the earth, which looks towards the Cynosure, is called Boreal and Arctic; the other one, opposite to this, is called Austral and Antarctic. Nor do these also exist on the earth or on a terrella for the sake of the turning merely; but they are also limits of direction and position, both as respects destined districts of the world, and also for correct turnings among themselves.

CHAP. XIIII.

Why at the Pole itself the Coition is stronger than in *the other parts intermediate between the æquator and the pole;* and on the proportion of forces of the coition in *various parts of the earth and of the terrella.*

Observation has already been made that the highest power of alluring exists in the pole, and that it is weaker and more languid in the parts adjacent to the æquator. And as this is apparent in the declination, because that disponent and rotational virtue has an augmentation as one proceeds from the Æquator towards the poles: so also the coition of magneticks grows increasingly fresh by the same steps, and in the same proportion. For in the parts more remote from the poles the loadstone does not draw magneticks straight down towards its own viscera; but they tend obliquely and they allure obliquely. For as the smallest chords in a circle differ from the diameter, so much do the forces of attracting differ between themselves in different parts of the terrella. For since attraction is coition towards a {82}
body, but magneticks run together by their versatory tendency, it comes about that in the diameter drawn from pole to pole the body appeals directly, but in other places less directly. So the less the magnetick is turned toward the body, the less, and the more feebly, does it approach and adhære. Just as if A B were the poles and a bar of iron or a magnetick fragment C is allured at the part E; yet the end laid hold of does not tend towards the centre of the loadstone, but verges obliquely towards the pole; and a chord drawn from that end obliquely as the attracted body tends is short; therefore it has less vigour and likewise less inclination. But as a greater chord proceeds from a body at F, so its action is stronger; at G still longer; longest at A, the pole (for the diameter is the longest way) to which all the parts from all sides bring assistance, in which is constituted, as it were, the citadel and tribunal of the whole province, not from any worth of its own, but because a force resides in it contributed from all the other parts, just as all the soldiers bring help to their own commander. Wherefore also a slightly longer stone attracts more than a spherical one, since the length from pole to pole is extended, even if the stones are both from the same mine and of the same weight and size. The way from pole to pole is longer in a longer stone, and the forces brought together from other parts are not so scattered as in a round magnet and terrella, and in a narrow one they agree more and are better united, and a united stronger force excels and is preeminent. A much weaker office, however, does a plane or oblong stone perform, when the length is extended according to the leading of the parallels, and the pole stops neither on the apex nor in the circle and orbe, but is spread over the flat. Wherefore also it invites a friend wretchedly, and feebly retains him, so that it is esteemed as one of an abject and contemptible class, according to its less apt and less suitable figure.



CHAP. XV.

{83}

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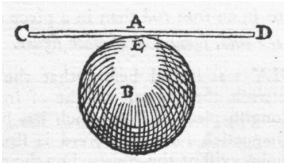
The Magnetick Virtue which is conceived in Iron is more apparent in an iron rod than in a piece of iron that *is round, square, or of other figure.*

Duly was it said before that the longer magnet attracts the greater weight of iron[167]; so also in a longish piece of iron which has been touched the magnetick force conceived is stronger when the poles exist at the ends. For the magnetick forces which are driven from the whole in every part into the poles are not scattered but united in the narrow ends. In square and other angular figures the influence is dissipated, and does not proceed in straight lines or in convenient arcs. Suppose also an iron globe have the shape of the earth, yet for the same reasons it drags magnetick substances less; wherefore a small iron sphere, when excited, draws another piece of iron more sluggishly than an excited rod of equal weight.

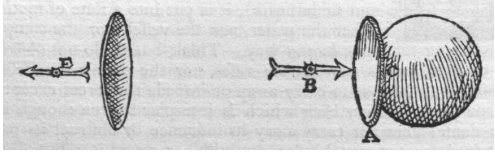
CHAP. XVI.

Showing that Movements take place by the Magnetical Vigour though solid bodies lie between; and on *the interposition of iron plates*.

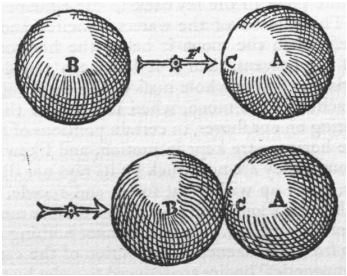
Float a piece of iron wire on the surface of water by transfixing it through a suitable cork; or set a versatory piece of iron on a pin or in a seaman's compass (a magnet being brought near or moved about underneath), it is put into a state of motion; neither the water, nor the vessel, nor the compass-box offering resistance in any way. Thick boards do not obstruct[168], nor earthen vessels nor marble vases, nor the metals themselves; nothing is so solid as to carry away or impede the forces excepting an iron plate. Everything which is interposed (even though it is very dense) does not carry away its influence or obstruct its path, or indeed in any way hinder, diminish, or retard it. But all the force is not suppressed by an iron plate, but it is in some measure diverted aside. For when the vigour passes into the middle of an iron plate within the orbe of the magnetick virtue or placed just opposite the pole of the stone, that virtue is scattered in very large measure towards its {84}
* extremities; so that the edges of a small round plate of suitable size allure iron wires on every side. This is also apparent in the case of a long iron wand, which, when it has been touched by a
* magnet in the middle, has a like verticity at either end.



B is a loadstone, C D a long rod magnetized in the middle A; E being the Boreal pole; C is an Austral end or pole; in like manner also the end D is another Austral pole. But observe here the exactness with which a versorium touched by a pole, when a round plate is interposed, turns
* towards the same pole in the same way as before the interposition, only weaker; the plate not standing in the way, because the vigour is diverted through the edges of the small plate, and passes out of its straight course, but yet the plate retains in the middle the same verticity, when it is in the neighbourhood of that pole, and close to it; wherefore the versorium tends towards the plate, having been touched by the same pole. If a loadstone is rather weak, a versorium hardly turns when a plate is put in between; for the vigour of the rather weak loadstone, being diffused
* through the extremities, passes less through the middle. But if the plate has been touched in this way by a pole in the middle and has been removed from the stone outside its orbe of virtue, then you will see the point of the same versorium tend in the contrary direction and desert the centre of the small plate, which formerly it desired; for outside the orbe of virtue it has an opposite verticity, in the vicinity the same; for in the vicinity it is, as it were, a part of the loadstone, and has the same pole.



A is an iron plate near the pole, B a versorium which tends with its point towards the centre of the small plate, which has been touched by the pole of the loadstone C. But if the same small plate be placed outside the orbe of magnetick virtue, the point will not turn towards its centre, {85}
but the cross E of the same versorium does. But an iron globe interposed (if it is not too large)
* attracts the point of the iron on the other side of the stone. For the verticity of that side is the same as that of the adjoining pole of the stone. And this turning of the cusp (that is, of the end touched by that pole) as well as of the cross-end, at a greater distance, takes place with an iron
* globe interposed, which would not happen at all if the space were empty, because the magnetick virtue is passed on and continued through magnetick bodies.



A is a terrella, B an iron globe; between the two bodies is F, a versorium whose point has been excited by the pole C. In the other figure A is a terrella, C its pole, B an iron globe; where the versorium tends towards C, the pole of the terrella, through the iron globe. So a versorium placed between a terrella and an iron globe vibrates more forcibly towards the pole of the terrella; because the loadstone sends an instantaneous verticity into the opposite globe. There is the same efficiency in the earth, produced from the same cause. For if a revolvable needle is shut up in a rather thick gold box (this metal indeed excels all others in density) or a glass or stone box, nevertheless that magnetick needle has its forces connected and united with the influences of the earth, and the iron will turn freely and readily (unhindered by its prison) to its desired
* points, North and South. It even does this when shut up in iron caverns, if they are sufficiently spacious. Whatever bodies are produced among us, or are artificially forged from things which are produced, consist of matter of the terrestrial globe; nor do those bodies hinder the prime forces of nature which are derived from their primary form, nor can they resist them except by contrary forms. But no forms of mixed bodies are inimical to the primary implanted earth-nature, although some often do not agree[169] with one another. But in the case of all those substances which have a material cause for their inclining (as amber, jet, sulphur), their action is impeded by {86}
the interposition of a body (as paper, leaves, glass, or the like) when that way is impeded and obstructed, so that that which exhales[170] cannot reach the corpuscle to be allured. Terrestrial and magnetick coition and motion, when corporeal impediments are interposed, is demonstrated also by the efficiencies of other chief bodies due to their primary form. The moon (more than all the stars) agrees with internal parts of the earth on account of its nearness and similarity in form. The moon produces the movements of the waters and the tides of the sea; twice it fills up the shores and empties them whilst it moves from a certain definite point in the sky back to the same point in a daily revolution. This motion of the waters is incited and the seas rise and fall no less when the moon is below the horizon and in the lowest part of the heavens, than if it had been raised at a height above the horizon. So the whole mass of the earth interposed[171] does not resist the action of the moon, when it is below the earth; but the seas bordering on our shores, in certain positions of the sky when it is below the horizon, are kept in motion, and likewise stirred by its power (though they are not struck by its rays nor illuminated by its light), rise, come up with great force, and recede. But about the reason of the tides anon[172]; here let it suffice to have merely touched the threshold of the question. In like manner nothing on the earth can be hidden from the magnetick disposition of the earth or of the stone, and all magnetical bodies are reduced to order by the dominant form of the earth, and loadstone and iron show sympathy with a loadstone though solid bodies be interposed.

CHAP. XVII.

On the Iron Cap of a Loadstone, with which it is armed at the pole (for the sake of the *virtue) and on the efficacy of the same.*

onceive a small round plate, concave in shape, of the breadth of a digit to be applied to the convex polar surface of a loadstone and skilfully attached; or a piece of iron shaped like an acorn, rising from the base into an obtuse cone, hollowed out a little and fitted to the surface of the stone, to be tied to the loadstone. Let the iron be the best steel, smoothed, shining, and even. A loadstone with such an appliance, which before only bore four ounces of iron, will now raise twelve. But the greatest force of a combining or rather united nature is seen when two loadstones, armed with iron caps, are so joined by their {87}
* concurrent (commonly called contrary) ends, that they mutually attract and raise one another. In this way a weight of twenty ounces is raised, when either stone unarmed would only allure four ounces of iron. Iron unites to an armed loadstone more firmly than to a loadstone; and on that account raises greater weights, because the pieces of iron stick more pertinaciously to one that is armed. For by the near presence of the magnet they are cemented together, and since the armature[173] conceives a magnetick vigour from its presence and the other conjoined piece of iron is at the same time endued with vigour from the presence of the loadstone, they are firmly bound together. Therefore by the mutual contact of strong pieces of iron, the cohesion is strong. Which thing is also made clear and is exhibited by means of rods sticking together, Bk. 3, chap 4[174]; and also when the question of the concretion of iron dust into a united body was discussed. For this reason a piece of iron set near a loadstone draws away any suitable piece of

iron from the loadstone, if only it touch the iron; otherwise it does not snatch it away, though in closest proximity. For magnetick pieces of iron within the orbe of virtue, or near a loadstone, do not rush together with a greater endeavour[175] than the iron and the magnet; but joined they are united more strongly and, as it were, cemented together, though the substance remain the same with the same forces acting.

CHAP. XVIII.

An armed Loadstone does not endow an excited piece of Iron with greater vigour *than an unarmed.*

* Suppose there are two pieces of iron, one of which has been excited by an armed loadstone, the other by one unarmed; and let there be applied to one of them another piece of iron of a weight just proportional to its strength, it is manifest that the remaining one in like manner raises the same and no more. Magnetick versoria also touched by an armed loadstone turn with the same velocity and constancy towards the poles of the earth as those magnetized by the same loadstone unarmed.

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CHAP. XIX.

Union with an armed Loadstone is stronger; *hence greater weights are raised; but the* coition is not stronger[176], but *generally weaker.*

* An armed magnet raises a greater weight, as is manifest to all; but a piece of iron moves towards a stone at an equal, or rather greater, distance when it is bare, without an iron cap. This must be tried with two pieces of iron of the same weight and figure at an equal distance, or with one and the same versorium, the test being made first with an armed, then with an unarmed loadstone, at equal distances.

CHAP. XX.

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An armed Loadstone raises an armed Loadstone, *which also attracts a third; which likewise* happens, though the virtue in the first *be somewhat small.*

Magnets armed cohære firmly when duly joined, and accord into one; and though the first be rather weak, yet the second one adhæres to it not only by the strength of the first, but of the second, which mutually give helping hands; also to the second a third often adheres and in the case of robust stones, a fourth to the third.

{89}

CHAP. XXI.

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If Paper or any other Medium be interposed, an armed loadstone raises no more than an *unarmed one.*

Observation has shown above that an armed loadstone does not attract at a greater distance than an unarmed one; yet raises iron in greater quantity, if it is joined to and made continuous with the iron. But if Paper be placed between, that intimate cohæsion of the metal is hindered, nor are the metals cemented together at the same time by the

operation of the magnet.

CHAP. XXII.

That an armed Loadstone draws Iron no more than an *unarmed one: And that an armed one is more strongly united* to iron is shown by means of an armed loadstone *and a polished cylinder of iron.*

If a cylinder be lying on a level surface, of too great a weight for an unarmed loadstone to lift, and (a piece of paper being interposed) if the pole of an armed loadstone be joined to the middle of it; if the cylinder were drawn from there by the loadstone, it would follow rolling; but if no medium were interposed, the cylinder would be drawn along firmly united with the armed loadstone, and in no wise rolling. But if the same loadstone be unarmed, it will draw the cylinder rolling with the same speed as the armed loadstone with the paper between or when it was wrapped in paper.

Armed loadstones of diverse weights, of the same ore vigour and form, cling and hang to pieces of iron of a convenient size and proportionate figure with an equal proportion of strength. The same is apparent in the case of unarmed stones. A suitable piece of iron being applied to the lower part of a loadstone, which is hanging from a magnetick body, excites its vigour, so that the loadstone hangs on more firmly. For a pendent loadstone clings more firmly to a magnetick body joined to it above with a hanging piece of iron added to it, than when lead or any other non-magnetick body is hung on. {90}

A loadstone, whether armed or unarmed, joined by its proper pole to the pole of another loadstone, armed or unarmed, makes the loadstone raise a greater weight by the opposite end[177]. A piece of iron also applied to the pole of a magnet produces the same result, namely, that the other pole will carry a greater weight of iron; just as a loadstone with a piece of iron superposed on it (as in this figure) holds up a piece of iron below, which it cannot hold, if the upper one be removed. Magneticks in conjunction make one magnetick. Wherefore as the mass increases, the magnetick vigour is also augmented.

An armed loadstone, as well as an unarmed one, runs more readily to a larger piece of iron and combines more firmly with a larger piece than with a lesser one.

CHAP. XXIII.

Magnetick Force causes motion towards unity, *and binds firmly together bodies which are united.*

Magnetick fragments cohære within their strength well and harmoniously together. Pieces of iron in the presence of a loadstone (even if they are not touching the loadstone) run together, seek one another anxiously and embrace one another, and when joined are as if they were cemented. Iron filings or the same reduced to powder inserted in paper tubes, placed upon a stone meridionally or merely brought rather close to it, coalesce into one body, and so many parts suddenly are concreted and combine; and the whole company of corpuscles thus conspiring together affects another piece of iron and attracts it, as if it constituted one integral rod of iron; and above the stone it is directed toward the North and South. But when they are removed a long way from the stone, the particles (as if loosed again) are separated and move apart singly. In this way also the foundations of the world are connected and joined and cemented together magnetically. So let Ptolemy of Alexandria, and his followers, and those philosophers of ours, be the less terrified if the earth do move round in a circle, nor threaten its dissolution. {91}

Iron filings, after being heated for a long time, are attracted by a loadstone, yet not so strongly or from so great a distance as when not heated. A loadstone loses some of its virtue by too great a heat; for its humour is set free, whence its peculiar nature is marred. Likewise also, if iron filings are well burnt in a reverberatory furnace and converted into saffron of Mars, they are not attracted by a loadstone; but if they are heated, but not thoroughly burnt, they do stick to a magnet, but less strongly than the filings themselves not acted upon by fire. For the saffron has become totally deformate, but the heated metal acquires a defect from the fire, and the forces in the enfeebled body are less excited by a loadstone; and, the nature of the iron being now ruined, it is not attracted by a loadstone.

CHAP. XXIIII.

A piece of Iron placed within the Orbe of a Loadstone hangs suspended in the air, if on account *of some impediment it cannot approach it.*

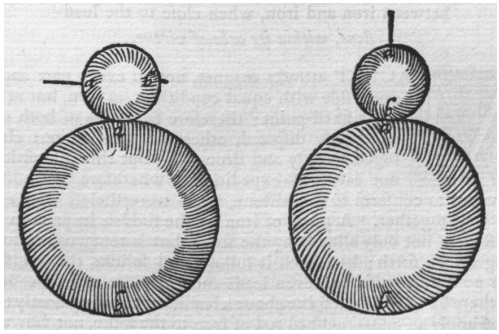
Within the magnetick orbe a piece of iron moves towards the more powerful points of the stone, if it be not hindered by force or by the material of a body placed between them; either it falls down from above, or tends sideways or obliquely, or flies up above. But if the iron cannot reach the stone on account of some obstacle, it cleaves to it and remains there, but with a less firm and constant connection, since at greater intervals or distances the alliance is less amicable. Fracastorio, in the eighth chapter of his *De Sympathia*, says that a piece of iron is suspended in the air, so that it can be moved neither up nor down, if a loadstone be placed above which is able to draw the iron up just as much as the iron itself inclines downwards with equal force; for thus the iron would be supported in the air: which thing is absurd; because the force of a magnet is always the stronger {92} the nearer it is. So that when a piece of iron is raised a very little from the earth by the force of the magnet, it needs must be drawn steadily on towards the magnet (if nothing else come in the way) and cleave to it. Baptista Porta suspends a piece of iron in the air[178] (a magnet being fixed above), and, by no very subtile process, the iron is detained by a slender thread from its lower part, so that it cannot rise up to the stone. The iron is raised upright by the magnet, although the * magnet does not touch the iron, but because it is in its vicinity; but when the whole iron on account of its greater nearness is moved by that which erected it, immediately it hurries with a swift motion to the magnet and cleaves to it. For by approaching the iron is more and more excited, and the coition grows stronger.

CHAP. XXV.

Exaltation of the power of the Magnet.

One loadstone far surpasses another in power, since one draws iron of almost its own weight, another can hardly stir some shreds. Whatever things, whether animals or plants, are endowed with life need some sort of nourishment, by which their strength not only persists but grows firmer and more vigorous. But iron is not, as it seemed to Cardan and to Alexander Aphrodiseus, attracted by the loadstone in order that it may feed on shreds of it, nor does the loadstone take up vigour from iron filings as if by a repast on victuals. Since Porta had doubts on this and resolved to test it, he took a loadstone of ascertained weight, and buried it in iron filings of not unknown weight; and when he had left it there for many months, he found the stone of greater weight, the filings of less. But the difference was so slender that he was even then doubtful as to the truth. What was done by him does not convict the stone of voracity, nor does it show any nutrition; for minute portions of the filings are easily scattered in handling. So also a very fine dust is insensibly born on a loadstone in some very slight quantity, by which something might have been added to the weight of the loadstone but which is only a surface accretion and might even be wiped off with no great difficulty. Some think that a weak and sluggish stone can bring itself back into better condition, and that a very powerful one also might present it with the highest powers. Do they acquire strength like animals when they eat and are sated? Is the medicine prepared by addition or subtraction? Is there {93} anything which can re-create this primary form or bestow it anew? And, certes, nothing can do this which is not magnetical. Magneticks can restore a certain soundness to magneticks (when not incurable); some can even exalt them beyond their proper strength; but when a body is at the height of perfection in its own nature, it is not capable of being strengthened further. So that that imposture of Paracelsus, who affirms that the force and virtue can be increased and transmuted tenfold, turns out to be the more infamous. The method of effecting this is as follows, viz., you make it semi-incandescent in a fire of charcoal (that is, you heat it very hot), so that it does not become red-hot, however, and immediately slake it, as much indeed as it can imbibe, in oil of saffron of Mars, made from the best Carynthian steel. "In this way you will be able so to strengthen a loadstone that it can draw a nail out of a wall and accomplish many other like wonderful things, which are not possible for a common loadstone." But a loadstone thus slaked in oil not only does not gain power, but suffers also a certain loss of its inborn strength. A loadstone is improved if polished and rubbed with steel. Buried in filings of the best iron or of pure steel, not rusty, it preserves its strength. Sometimes also a somewhat good and strong one gains some strength when it is rubbed on the pole of another, on the opposite part, and receives virtue. In all these experiments it is an advantage to observe the pole of the earth, and to adjust according to magnetick laws the stone which we wish to strengthen; which we shall set forth below. A somewhat powerful and fairly large loadstone increases the strength of a loadstone as it does of ∗ iron. A loadstone being placed over the boreal pole of a loadstone, the boreal pole becomes {94} stronger, and an iron rod (like an arrow) sticks to the boreal pole A, but not at all to the pole B. The pole A also, when it is at the top in a right line with the axis of both loadstones joined in accordance with magnetick laws, raises the rod to the perpendicular, which it cannot do if the large loadstone be removed, on account of its own weaker strength. But as a small iron globe, * when placed above the pole of a terrella, raises the rod to the perpendicular, so, when placed at

the side, the rod is not directed towards the centre of the globe, but is raised obliquely and cleaves anywhere, because the pole in a round piece of iron is always the point which is joined most closely to the pole of the terrella and is not constant as in a smaller terrella. The parts of the earth, as of all magneticks, are in agreement and take delight in their mutual proximity; if placed in the highest power, they do not harm their inferiors, nor slight them; there is a mutual love among them all, a perennial good feeling. The weaker loadstones are re-created by the more powerful, and the less powerful cause no harm to the stronger. But a powerful one attracts and turns a somewhat strong one more than it does an impotent one. Because a strenuous one confers a stronger activity, and itself hastens, flies up to the other, and solicits it more keenly; therefore there is a more certain and a stronger co-action and cohærency.



CHAP. XXVI.

Why there should appear to be a greater love between *iron and loadstone, than between loadstone and loadstone, or* between iron and iron, when close to the loadstone, *within its orbe of virtue.*

Magnet attracts magnet, not in every part and on every side with equal conditions, as iron, but at one and a fixed point; therefore the poles of both must be exactly disposed, otherwise they do not cleave together duly and strongly. But this disposition is not easy and expeditious; wherefore a loadstone seems not to conform to a loadstone, when nevertheless they agree very well together. A piece of iron by the sudden impression of a loadstone is not only allured by the stone, but is renewed, its forces being drawn forth; by which it follows and solicits the loadstone with no less impulse, and even leads another piece of iron captive. Let there be a small iron spike above a loadstone clinging firmly to it; if you apply an unmagnetized rod of iron to the spike, not, however, so that it touches the stone, you {95} will see the spike when it has touched the iron, leaving the loadstone, follow the rod, try to grasp it by leaning toward it, and (if it should touch it) cleave firmly to it: for a piece of iron, when united and joined to another piece of iron placed within the orbe of virtue of the loadstone, draws it more strongly than does the loadstone itself. The natural magnetick virtue, confused and dormant in the iron, is aroused by the loadstone, is linked to the loadstone, and rejoices with it in its primary form; then smelted iron becomes a perfect magnetick, as robust as the loadstone itself. For as the one imparts and stirs, so the other conceives, and being stirred remains in virtue, and pours back the forces also by its own activity. But since iron is more like iron than loadstone, and the virtue in both pieces of iron is exalted by the proximity of the loadstone, so in the loadstone itself, in case of equal strength, likeness of substance prevails, and iron gives itself up rather to iron, and they are united by their very similar homogenic powers. Which thing happens not so much from a coition, as from a firmer unition; and a knob or snout of steel, fixed skilfully on the pole of the stone, raises greater weights of iron than the stone of itself could. When steel or iron is smelted from loadstone or iron ore, the slag and corrupt substances are separated from the better by the fusion of the material; whence (in very large measure) that iron contains the nature of the earth, purified from alien flaw and blemish, and more homogenic and perfect, though deformed by the fusion. And when that material indeed is provoked by a loadstone, it conceives the magnetick virtues, and within their orbe is raised in strength more than the weaker loadstone, which with us is often not free from some admixture of impurities.

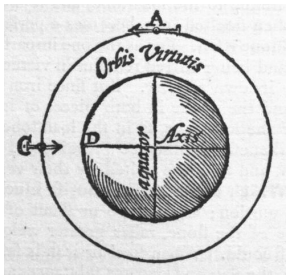
CHAP. XXVII.

*

The Centre of the Magnetick Virtues in the earth is the centre of the earth; and in a terrella *is the centre of the stone.*

Rays of magnetick virtue spread out in every direction in an orbe; the centre of this orbe is not at the pole (as Baptista Porta reckons, Chap. 22), but in the centre of the stone and of the terrella. So also the centre of the earth is the centre of the magnetick motions of the earth; though magneticks are not borne directly toward the centre by magnetical motion, except when they are attracted by the true pole. For since the formal power of the stone and of the earth does not promote anything but the unity {96} and conformity of disjoined bodies, it comes about that everywhere at an equal distance from the centre or from the circumference, just as it seems to attract perpendicularly at one place, so at another it is able even to dispose and to turn, provided the stone is not uneven in virtue. For if at

* the distance C from the pole D the stone is able to allure a versorium, at an equally long interval above the æquator at A that stone can also direct and turn the versorium. So the very centre and middle of the terrella is the centre of its virtue, and from this to the circumference of the orbe (at equal intervals on every side) its magnetick virtues are emitted.



CHAP. XXVIII.

A Loadstone attracts magneticks not only to a fixed point or pole, but to every part of a *terrella save the æquinoctial zone.*

Coitions are always more powerful when poles are near poles, since in them by the concordancy of the whole there exists a stronger force; wherefore the one embraces the other more strongly. Places declining from the poles have attractive forces, but a little weaker and languid in the ratio of their distance; so that at length on the æquinoctial circle they are utterly enervated and evanescent. Neither do even the poles attract as mathematical points; nor do magneticks come into conjunction by their own poles, only on the poles of a loadstone. But coition is made on every part of the periphery, both {97} Northern and Southern, by virtue emanating from the whole body; magneticks nevertheless incline languidly towards magneticks in the parts bordering on the æquator, but quickly in places nearer the pole. Wherefore not the poles, not the parts alone nearest to the pole allure and invite magneticks, but magneticks are disposed and turned round and combine with magneticks in proportion as the parts facing and adjoined unite their forces together, which are always of the same potency in the same parallel, unless they are distributed otherwise from causes of variation.

CHAP. XXIX.

On Variety of Strength due to Quantity *or Mass.*

Quite similar in potency are those stones which are of the same mine, and not corrupted by adjacent ores or veins. Nevertheless that which excels in size shows greater powers, since it seizes greater weights and has a wider orbe of virtue. For a loadstone weighing one ounce does not lift a large nail as does one weighing a pound, nor does it rule so widely, nor extend its forces; and if from a loadstone of a pound weight a portion is taken away, something of its power will be seen to go also; for when a portion is abstracted the virtue is lessened. But if that part is properly applied and united to it, though it is * not fastened to nor grown into it, yet by the application it obtains its pristine power and its vigour returns. Sometimes, however, when a part is taken away, the virtue turns out to be stronger on * account of the bad shape of the stone, namely, when the vigour is scattered through inconvenient angles. In various species the ratio is various, for one stone of a drachm weight draws more than another of twenty pounds. Since in very many the influence is so effete that it can hardly be perceived, those weak stones are surpassed by prepared pieces of clay. But, it may be asked[179], if a stone of the same species and goodness weighing a drachm would seize upon a drachm of iron, would a stone of an ounce weight seize on an ounce, a pound on a pound, and so on? And this is indeed true; for it both strains and remits its strength proportionately, so that if a loadstone, one drachm of which would attract one drachm of iron, were in equal proportion applied either to a suitably large obelisk or to an immense pyramid of iron, it would lift it directly in such proportion and would draw it towards itself with no greater effort of its nature or trouble {98} than a loadstone of a drachm weight embraces a drachm. But in all such experiments as this let the vigour of the magnets be equal; let there be also a just proportion in all of the shapes of the stones, and let the shape of the iron to be attracted be the same, and the goodness of the metal, and let the position of the poles of the loadstones be most exact. This is also no less true in the case of an armed loadstone than of an unarmed one. For the sake of experiment, let there be given a loadstone of eight ounces weight, which when armed lifts twelve ounces of iron; if you cut * off from that loadstone a certain portion, which when it has been reduced to the shape of the former whole one is then only of two ounces, such a loadstone armed lifts a piece of iron applied

to it of three ounces, in proportion to the mass. In this experiment also the piece of iron of three ounces ought to have the same shape as the former one of twelve ounces; if that rose up into a cone, it is necessary that this also in the ratio of its mass should be given a pyramidal shape proportioned to the former.

CHAP. XXX.

The Shape and Mass of the Iron are of most *importance in coition.*

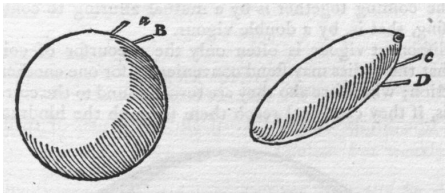
Observation has shown above that the shape and mass of the loadstone have great influence in magnetick coitions; likewise also the shape and mass of the iron bodies give back more powerful and steady forces. Oblong iron rods are both drawn more quickly to a loadstone and cleave to it with greater obstinacy than round or square pieces, for the same reasons which we have proven in the case of the loadstone. But, moreover, this is also worthy of observation, that a smaller piece of iron, to which is hung a weight of another material, so that it is altogether in weight equal to another large whole piece of
* iron of a right weight (as regards the strength of the loadstone), is not lifted by the loadstone as the larger piece of iron would be. For a smaller piece of iron does not join with a loadstone so firmly, because it sends back less strength, and only that which is magnetick conceives strength; the foreign material hung on cannot acquire magnetick forces.

CHAP. XXXI.

{99}

On Long and Round Stones.

Pieces of iron join more firmly with a long stone than with a round one, provided that the pole of the stone is at the extremity and end of its length; because, forsooth, in the case of a long stone, a magnetick is directed at the end straight towards the body in which the virtue proceeds in straighter lines and through the longer diameter. But a somewhat long stone has but little power on the side, much less indeed than a
* round one. It is demonstrable[180], indeed, that at A and B the coition is stronger in a round stone than at C and D, at like distances from the pole.



CHAP. XXXII.

Certain Problems and Magnetick Experiments about the Coition, and Separation, and regular Motion *of bodies magnetical.*

* Equal loadstones come together with equal incitation.

* Also magnetick bodies of iron, if alike in all respects, come together when excited with similar incitation.

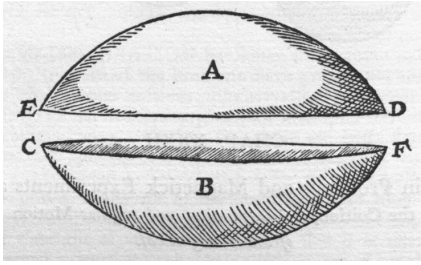
* Furthermore, bodies of iron not excited by a loadstone, if they are alike and not weighed down by their bulk, move towards one another with equal motion.

Two loadstones, disposed on the surface of some water in suitable skiffs, if they are drawn up {100}
suitably within their orbes of virtue, incite one another mutually to an embrace. So a
* proportionate piece of iron in one skiff hurries with the same speed towards the loadstone as the loadstone itself in its boat strives towards the iron. From their own positions, indeed, they are so borne together, that they are joined and come to rest at length in the middle of the space. Two
* iron wires magnetically excited, floating in water by means of suitable pieces of cork, strive to touch and mutually strike one another with their corresponding ends, and are conjoined.

* Coition is firmer and swifter than repulsion and separation in equal magnetick substances. That magnetick substances are more sluggishly repelled than they are attracted is manifest in all

magnetical experiments in the case of stones floating on water in suitable skiffs; also in the case of iron wires or rods swimming (transfixed through corks) and well excited by a loadstone, and in the case of versoria. This comes about because, though there is one faculty of coition, another of conformation or disposition, repulsion and aversion is caused merely by something disposing; on the other hand, the coming together is by a mutual alluring to contact and a disposing, that is, by a double vigour.

A disponent vigour is often only the precursor of coition, in order that the bodies may stand conveniently for one another before conjunction; wherefore also they are turned round to the corresponding ends, if they can [not][181] reach them through the hindrances.



If a loadstone be divided through a meridian into two equal parts, the separate parts mutually
* repel one another, the poles being placed directly opposite one another at a convenient and equal distance. They repel one another also with a greater velocity than when pole is put opposite pole incongruously. Just as the part B of the loadstone, placed almost opposite the part A, repels it floating in its skiff, because D turns away from F, and E from C; but if B is exactly joined with A again, they agree and become one body magnetical; but in proximity they raise enmities. But if {101} one part of the stone is turned round, so that C faces D and F faces E, then A pursues B within its orbe until they are united.

The Southern parts of the stone avoid the Southern parts, and the Northern parts the Northern. Nevertheless, if by force you move up the Southern cusp of a piece of iron too near the Southern part of the stone, the cusp is seized and both are linked together in friendly embraces: because it immediately reverses the implanted verticity of the iron, and it is changed by the presence of the more powerful stone, which is more constant in its forces than the iron. For they come together according to their nature, if by reversal and mutation true conformity is produced, and just coition, as also regular direction. Loadstones of the same shape, size, and vigour, attract one another mutually with like efficacy, and in the opposite position repel one another mutually with a like vigour.

* Iron rods not touched, though alike and equal, do yet often act upon one another with different forces; because as the reasons of their acquired verticity, also of their stability and vigour, are different, so the more strongly they are excited, the more vigorously do they incite.

* Pieces of iron excited by one and the same pole mutually repel one another by those ends at which they were excited; then also the opposite ends to those in these iron pieces raise enmities one to another.

* In versoria whose cusps have been rubbed, but not their cross-ends, the crosses mutually repel one another, but weakly and in proportion to their length.

* In like versoria the cusps, having been touched by the same pole of the loadstone, attract the cross-ends with equal strength.

* In a somewhat long versorium the cross-end is attracted rather weakly by the cusp of a shorter iron versorium; the cross of the shorter more strongly by the cusp of the longer, because the cross of the longer versorium has a weak verticity, but the cusp has a stronger.

* The cusp of a longer versorium drives away the cusp of a shorter one more vehemently than the cusp of the shorter the cusp of the longer, if the one is free upon a pin, and the other is held in the hand; for though both were equally excited by the same loadstone, yet the longer one is stronger at its cusp on account of its greater mass.

* The Southern end of an iron rod which is not excited attracts the Northern, and the Northern the Southern; moreover, also the Southern parts repel the Southern, and the Northern the Northern.

If magnetick substances are divided or in any way broken in pieces, each part has a Northern and a Southern end.

* A versorium is moved as far off by a loadstone when an obstacle is put in the way, as through air {102} and an open medium.

* Rods rubbed upon the pole of a stone strive after the same pole and follow it. Therefore Baptista Porta errs when he says, chapter 40[182], "If you put that part to it from which it received its force, it will not endure it, but drives it from it, and draws to it the contrary and opposite part."

The principles of turning round and inclining are the same in the case of loadstone to loadstone, of loadstone to iron, of iron also to iron.

When magnetick substances which have been separated by force and dissected into parts flow together into a true union and are suitably connected, the body becomes one, and one united virtue, nor have they diverse ends.

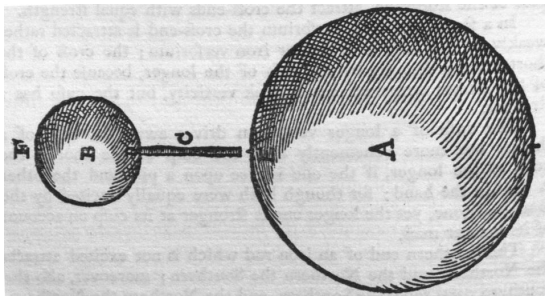
* The separate parts assume two opposite poles, if the division has not been made along a parallel: if the division has been made along a parallel, they are able to retain one pole in the same site as before.

Pieces of iron which have been rubbed and excited by a loadstone are more surely and swiftly seized by a loadstone at fitting ends than such as have not been rubbed.

* If a spike is set up on the pole of a loadstone, a spike or style of iron placed on the upper end is strongly cemented to it, and draws away the erect spike from the terrella when motion is made.

* If to the lower end of the erect spike the end of another spike is applied, it does not cohære with it, nor do they unite together.

As a rod of iron draws away a piece of iron from a terrella, so is it also with a minute loadstone and a lesser terrella, though weaker in strength.



The piece of iron C comes into conjunction with the terrella A, and the vigour in it is magnetically exalted and excited, both in the adjoining end and in the other also which is turned away through its conjunction with the terrella. The end that is turned away also conceives vigour from the {103}
loadstone B; likewise the pole D of that loadstone is powerful on account of its suitable aspect and the nearness of the pole E of the terrella. Several causes therefore concur why the piece of iron C should cleave to the terrella B, to which it is joined more firmly than to the terrella A; the vigour excited in the rod, the vigour also excited in the stone B, and the strength implanted in B concur; therefore D is more firmly cemented magnetically with C than E with C.

But if you were to turn the vertex F round to the iron C, C would not adhære to F as formerly to D; for stones so arranged being within the orbe of virtue are placed contrary to natural order; wherefore F does not receive power from E.

* Two loadstones or excited pieces of iron, duly cohæring, fly asunder on the approach of another more powerful loadstone or magnetized piece of iron. Because the new-comer repels the other with its opposing face, and dominates it, and ends the relationship of the two which were formerly joined. So the forces of the other are lessened and succumb; but if it conveniently could, being diverted of its association with the weaker, and rolling round, it would turn about to the stronger. Wherefore also magnetick bodies suspended in the air fall when a loadstone is brought near them with an opposing face, not (as Baptista Porta teaches) because the faculty of both those which were joined before grows faint and torpid, for no face can be hostile to both the ends which cohære, but to one only; and when the stronger loadstone, coming fresh with opposing face, impels this further from it, it is put to flight by the friendly reception of the former.

CHAP. XXXIII.

On the Varying Ratio of Strength, and of the Motion *of coition, within the orbe of virtue.*

Should a very large weight, which at a very small distance is drawn towards a loadstone, be divided into ever so many equal parts, and should the radius of the orbe of magnetick attraction be divided into the same number of parts, the like named parts of the weight will correspond to the intermediate parts of the radius.

The orbe of virtue extends more widely than the orbe of motion of any magnetick; for the magnetick is affected at its extremity, even if it is not moved with local motion, which effect is produced by the loadstone being brought nearer. A small versorium also is turned when a good {104}
distance off, even if at the same distance it would not flow towards the loadstone, though free and disengaged from impediment.

The swiftness of the motion of a magnetick body to a loadstone is dependent on either the power of the loadstone, on its mass, on its shape, on the medium, or on its distance within the magnetick orbe.

* A magnetick moves more quickly towards a more powerful stone than towards a sluggish one in proportion to the strength, and [as appears] by a comparison of the loadstones together. A lesser mass of iron also is carried more quickly towards a loadstone, just as also one that is a little longer in shape. The swiftness of magnetick motion towards a loadstone is changed by reason of the medium; for bodies are moved more quickly in air than in water, and in clear air than in air that is thick and cloudy.

  By reason of the distance, the motion is quicker in the case of bodies near together than when they are far off. At the limits of the orbe of virtue of a terrella a magnetick is moved feebly and slowly. At very short distances close to the terrella the moving impetus is greatest.

* A loadstone which in the outmost part of its orbe of virtue hardly moves a versorium when one foot removed from it, doth, if a long piece of iron is joined to it, attract and repel the versorium more strongly with its opposite poles when even three feet distant. The result is the same whether the loadstone is armed or unarmed. Let the iron be a suitable piece of the thickness of the little finger.

  For the vigour of the loadstone excites verticity in the iron and proceeds in the iron and through the iron much further than it extends through the air.

* The vigour proceeds even through several pieces of iron (joined to one another end to end), not so regularly, however, as through one continuous solid.

  Dust of steel placed upon paper rises up when a loadstone is moved near above it in a sort of steely hairiness; but if the loadstone is placed below, such a hairiness is likewise raised.

* Steel dust (when the pole of a loadstone is placed near) is cemented into one body; but when it desires coition with the loadstone, the mass is split and it rises in conglomerated parts.

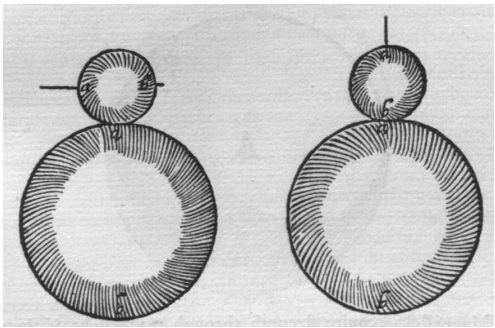
  But if there is a loadstone beneath the paper, the mass is split in the same way and many portions result, each of which consists of very many parts, and remains cemented together, as individual bodies. Whilst the lower parts of these pursue greedily the pole of the loadstone placed directly beneath, even they also are raised up as magnetick wholes, just as a small iron wire of the length of a grain or two grains of barley is raised up, both when the loadstone is moved near both beneath and above.

CHAP. XXXIIII.

{105}

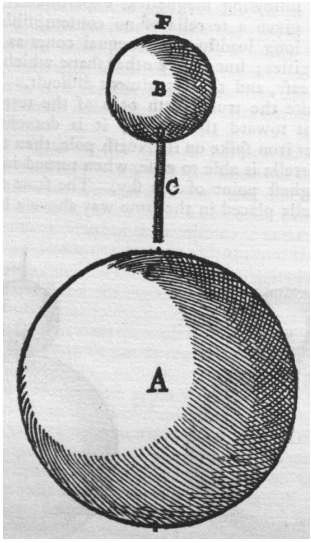
Why a Loadstone should be stronger in its poles
in a different ratio; as well in the Northern
regions as in the Southern.

*  he extraordinary magnetick virtue of the earth is remarkably demonstrated by the subtility of the following magnetical experiment. Let there be given a terrella of no contemptible power, or a long loadstone with equal cones as polar extremities; but in any other shape which is not exactly round error is easy, and the experiment difficult. In the Northern regions, raise the true North pole of the terrella above the horizon straight toward the zenith; it is demonstrable that it raises up a larger iron spike on its North pole, than the South pole of the same terrella is able to raise, when turned in the same way toward the highest point of the sky. The same thing is shown by a small terrella placed in the same way above a larger.



Let *a b* be the earth or a somewhat large terrella, also *a b* a smaller terrella. There is set up above the Northern pole of the smaller terrella a spike larger than the pole *b* of the smaller terrella can raise, if it is turned round to the higher parts. And the pole *a* of the smaller terrella {106}
has its strength from the larger, declining from the Zenith to the plane of the horizon or to the
* level. But now, if, leaving the terrella disposed in the same way, you bring a piece of iron to the lower and Southern pole, it will attract and retain a greater weight than the Boreal pole could, if it were turned round to the lower parts. Which thing is demonstrated thus: let A be the earth or a terrella; E the Boreal pole or some place in some great latitude; B a rather large terrella above the earth or a smaller terrella on the top of a larger; D its Southern pole. It is manifest that D (the

Southern pole) attracts a larger piece of iron, C, than F (the Boreal pole) will be able to, if it is turned round downward to the position D, toward the earth or the terrella in the Northern regions.



Magneticks acquire strength through magneticks, if they are properly placed according to their nature, in near neighbourhood and within the orbe of virtue. Wherefore when a terrella is placed on the earth or on a terrella, so that its Southern pole is turned round toward the Northern pole, its Northern pole, however, turned away from the Northern pole, the influence and strength of its {107}
poles are increased. And so the Northern pole of a terrella in such a position lifts up a larger spike than the Southern pole, if the Southern pole is turned away. Similarly the Southern pole in a proper and natural arrangement, acquiring strength from the earth or from a larger terrella,
* attracts and retains larger rods of iron. In the other part of the terrestrial globe toward the South, as also in the Austral portion of a terrella, the reasoning is converse; for the Southern pole of the terrella being turned away is more robust, as also the Northern pole when turned round. The more a region on the earth is distant from the æquinoctial (as also in a larger terrella), the larger is the accession of strength perceived; near the æquator, indeed, the difference is small, but on the æquator itself null; at the poles finally it is greatest.

CHAP. XXXV.

On a Perpetual Motion Machine, mentioned by authors, by means of the attraction *of a loadstone*.

Cardan writes[183] that out of iron and the Herculean stone can be made a perpetual motion machine; not that he himself had ever seen one, but only conceived the idea from an account by Antonius de Fantis[184], of Treves. Such a machine he describes, Book 9, *De Rerum Varietate*. But they have been little practised in magnetick experiments who forge such things as that. For no magnetick attraction can be greater (by any skill or by any kind of instrument) than the retention. Things which are joined and those which are approaching near are retained with a greater force than those which are enticed and set in motion, and are moved; and that coition is, as we have shown above, a motion of both, not an attraction of one. Such a machine Peter Peregrinus feigned many centuries before or else depicted one which he had received from others, and one which was much better fitted for the purpose. Johannes Taysnier published it also, spoiled by wretched figures, and copied out the whole theory of it word for word. O that the gods would at length bring to a miserable end such fictitious, crazy, deformed labours, with which the minds of the studious are blinded!

CHAP. XXXVI. {108}

How a more robust Loadstone may be *recognized*.

Very powerful loadstones sometimes lift into the air a weight of iron equal to their own; a weak one barely attracts a slender wire. Those therefore are more robust which appeal to and retain larger bodies, if there is no defect in their form, or the pole of the stone is not suitably moved up. Moreover, when placed in a boat a keener influence turns its own poles round more quickly to the poles of the earth or the limits of

variation on the horizon. One which performs its function more feebly indicates a defect and an effete nature. There must always be a similar preparation, a similar figure, and a like size; for in such as are very dissimilar and unlike, the experiment is doubtful. The method of testing the strength is the same also with a versorium in a place somewhat remote from a loadstone; for the one which is able to turn the versorium round at the greater distance, that one conquers and is held the more potent. Rightly also is the force of a loadstone weighed in a balance by B. Porta; a piece of loadstone is placed in one scale-pan, in the other just as much weight of something else, so that the scale-pans hang level. Soon a piece of iron lying on the table is adjusted so that it sticks to the loadstone placed in the scale, and they cling together most perfectly, according to their friendly points; into the other scale-pan sand is gradually thrown, and that until the scale in which the loadstone is placed is separated from the iron. Thus by weighing the weight of sand, the magnetick force becomes known. Similarly also it will be pleasing to try with another stone, in equilibrium, the weight of the sand being observed, and to find out the stronger by means of the weights of sand. Such is the experiment of Cardinal Cusan in his *De Staticis*[185], from whom it would seem that B. Porta learnt the experiment. The better loadstones turn themselves round more quickly toward the poles or points of variation; then they also lead along and turn round more quickly, according to the greater quantity and mass of wood, a boat and other stuff. In a declination instrument, the more powerful force of a loadstone is looked for and required. Those therefore are more lively when they get through their work readily, and pass through and come back again with speed, and swiftly at length settle at their own point. Languid and effete ones move more sluggishly[186], settle more tardily, adhære more uncertainly, and are easily disturbed from their possession.

CHAP. XXXVII.

{109}

Use of a Loadstone as it affects *iron.*

By magnetick coition we test iron ore in a blacksmith's forge. It is burnt, broken in pieces, washed and dried, in which way it lays down its alien humours; in the bits collected from the washing is placed a loadstone, which attracts the iron dust to itself; this, being brushed off with feathers, is received in a crucible, and the loadstone is again placed in the bits collected from the washing, and the dust wiped off, as long as any remains which it will attract to itself. This is then heated in the crucible along with *sal nitri*[187] until it is liquid, and from this a small mass of iron is cast. But if the loadstone draws the dust to itself quickly and readily, we conjecture that the iron ore is rich; if slowly, poor; if it seems altogether to reject it, there is very little iron in it or none at all. In like manner iron dust can be separated from another metal. Many tricks there are also, when iron is secretly applied to lighter bodies, and, being attracted by the motion of a loadstone which is kept out of sight, causes movements which are amazing to those who do not know the cause. Very many such indeed every ingenious mechanician will perform by sleight of hand, as if by incantations and jugglery[188].

CHAP. XXXVIII.

On Cases of Attraction in other Bodies.

Very often the herd of philosophizers and plagiarists repeat from the records of others in natural philosophy opinions and errors about the attractions of various bodies; as that Diamond attracts iron, and snatches it away from a magnet; that there are various kinds or magnets, some which attract gold, others silver, brass, lead; even some which attract flesh, water, fishes. The flame of sulphur is said to seek iron and stones; so white naphtha is said to attract fire. I have said above that inanimate natural bodies do not {110} attract, and are not attracted by, others on the earth, excepting magnetically or electrically. Wherefore it is not true that there are magnets which attract gold or other metals; because a magnetick substance draws nothing but magnetick substances. Though Fracastorio says that he has shown a magnet drawing silver; if this were true, it must have happened on account of iron skilfully mixed with that silver or concealed in it, or else because nature (as she does sometimes, but rarely) had mixed iron with the silver; iron indeed is rarely mixed with silver by nature; silver with iron very rarely or never. Iron is mixed with silver by forgers of false coin or from the avarice of princes in the coining of money, as was the case with the denarius of Antony[189], provided that Pliny is recording a true incident. So Cardan (perhaps deceived by others) says that there is a certain kind of loadstone which draws silver; he adds a most foolish test of this: "If therefore" (he says) "a slender rod of silver be steeped in that in which a versatory needle has stood, it will turn toward silver (especially toward a large quantity) although it be buried; by this means anyone will be able easily to dig up concealed treasures." He adds that "it should be very good stone, such as he has not yet seen." Nor indeed will either he or anyone else ever see such a stone or such an experiment. Cardan brings forward an attraction of flesh, wrongly so named and

very dissimilar from that of the loadstone; for his *magnes creagus* or flesh-magnet, from the experiment that it sticks to the lips, must be hooted out from the assembly of loadstones, or by all means from the family of things attractive. Lemnian earth, ruddle, and very many minerals do this, and yet they are fatuously said to attract. He will have it that there is another loadstone, as it were, a third species, into which, if a needle is driven and afterwards stuck into the body, it is not felt. But what has attraction to do with stupefaction, or stupor with a Philosopher's intellect, when he is discoursing about attraction? There are many stones, both found in nature and made by art, which have the power of stupefying. Sulphur flame is said by some to attract, because it consumes certain metals by its power of penetration. So white naphtha attracts flame, because it gives off and exhales an inflammable vapour, on which account it is kindled at some distance, just as the smoke of a recently extinguished candle takes fire again from another flame; for fire creeps to fire through an inflammable medium. Why the sucking fish Echineis or the Remora should stay ships has been variously treated by Philosophers, who are often accustomed to fit this fable (as many others) to their theories, before they find out whether the thing is so in nature. Therefore, in order that they may support and agree with the fatuities of the ancients, they put forward even the most fatuous ratiocinations and ridiculous problems, cliffs that attract, where the sucking fish tarry, and the necessity of some vacuum, I know not what, or how produced. {111} Pliny and Julius Solinus make mention of a stone Chatochitis[190]. They say that it attracts flesh, and keeps hold of the hands, just as a loadstone does iron, and amber chaff. But that happens only from a stickiness and from glue contained in it, since it sticks more easily to the hands when they are warm. Sagda or Sagdo[191], of the colour of a sard, is a precious stone mentioned by Pliny, Solinus, Albertus, and Evax[192]; they describe its nature and relate, on the authority of others, that it specially attracts wood to itself. Some even babble that woods cannot be wrenched away except they are cut off. Some also narrate that a stone is found which grows pertinaciously into ships, in the same way as certain testacea on long voyages. But a stone does not draw because it sticks; and if it drew, it would certainly draw shreds electrically, Encelius saw in the hands of a sailor such a stone of feeble virtue, which would hardly attract even the smallest twigs; and in truth, not of the colour of the sard. So Diamond, Carbuncle, Crystal, and others do attract. I pass over other fabulous stones; Pantarbe, about which Philostratus writes that it draws other stones to itself; Amphitane also, which attracts gold. Pliny in his origin of glass will have it that a loadstone is an attractor of glass, as well as of iron. For in his method of preparing glass, when he has indicated its nature, he subjoins this about loadstone. "Soon (such is the astute and resourceful craft) it was not content to have mixed natron; loadstone also began to be added, since it was thought to attract to itself the liquor of glass (as it does iron)." Georgius Agricola writes that to the material of glass (sand and natron) one part also of loadstone is added. "Because that force is believed, in our times just as in former times, to attract the liquor of glass to itself, as it attracts iron to itself, purges it when drawn, and makes clear glass from green or muddy; but the fire afterwards burns up the loadstone." It is true indeed that some sort of *magnes* (as the magnesia of the glass-makers imbued with no magnetick virtues) is sometimes put in and mixed with the material of the glass; not, however, because it attracts glass. But when a loadstone is burnt, it does not lay hold of iron at all, nor is iron when red-hot allured by any loadstone; and loadstone also is burnt up by more powerful fires and loses its attractive potency. Nor is this a function of loadstone alone in the glass furnaces; but also of certain pyrites and of some easily combustible iron ores, which are the only ones used by our glass-makers, who make clear, bright glass. They are mixed with the sand, ashes, and natron (just as they are accustomed to make additions in the case of metallick ores whilst they are smelted), so that when the material slows down into glass, the green and muddy colour of the glass may be purged by the penetrating heat. For no other material becomes so hot, or bears the fire for such a convenient {112} time, until the material of the glass is perfectly fluid, and is at the same time burnt up by that ardent fire. It happens, however, sometimes, that on account of the magnetick stone, the magnesia, or the ore, or the pyrites, the glass has a dusky colour, when they resist the fire too much and are not burnt up, or are put in in too great quantity. Wherefore manufacturers are seeking for a stone suitable for them, and are observing also more diligently the proportion of the mixture. Badly therefore did the unskilful philosophy of Pliny impose upon Georgius Agricola and the more recent writers, so that they thought the loadstone was wanted by glass-makers on account of its magnetick strength and attraction. But Scaliger in *De Subtilitate ad Cardanum*, in making diamond attract iron, when he is discussing magneticks, wanders far from the truth, unless it be that diamond attracts iron electrically, as it attracts wood, straws, and all other minute bodies when it is rubbed. Fallopius reckons that quicksilver draws metals by reason of an occult property, just as a loadstone iron, amber chaff. But when quicksilver enters metals, it is wrongly called attraction. For metals imbibe quicksilver, just as clay water; nor do they do this unless they are touching, for quicksilver does not allure gold or lead to itself from afar, but they remain motionless in their places.

CHAP. XXXIX.

On Bodies which mutually repel one another.

Writers who have discoursed on the forces of bodies which attract others have also spoken about the powers of bodies which repel, but especially those who have instituted classes for natural objects on the basis of sympathy and antipathy. Wherefore it would seem necessary for us to speak also about the mutual strife of bodies, so that published errors should not creep further, and be received by all to the ruin of true philosophy. They say that, just as like things attract for the sake of preservation, so unlike and contrary things for the same purpose mutually repel and put one another to flight. This is evident in the reaction of many things, but it is most manifest in the case of plants and animals, which attract kindred and familiar things, and in like manner reject foreign and unsuitable things. But in other bodies there is not the same reason, so that when they are separated, they should come together by mutually attracting one another. Animals take food (as {113} everything which grows), and draw it into their interior; they absorb the nourishment by certain parts and instruments (through the action and operation of the *anima*). They enjoy by natural instinct only the things set in front of them and near them, not things placed afar off; and this without any alien force or motion. Wherefore animals neither attract any bodies nor drive them away. Water does not repel oil (as some think) because the oil floats on water; nor does water repel mud, because the mud, if mixed in water, settles down in time. This is a separation of unlike bodies or such as are not perfectly mixed as respects the material; the separated bodies nevertheless remain joined without any natural strife. Wherefore a muddy sediment settles quietly on the bottom of vessels, and oil remains on the top of the water and is not sent further away. A drop of water remains intact on a dry surface, and is not expelled from the dry substance. Wrongly therefore do those who discourse on these matters infer an antipathy (that is, the force of repelling by contrary passions); for there is no repelling force in them; and repulsion comes[193] from action, not from passion. But their greek vocables please them too much. We, however, must inquire whether there is any body which drives anything else further off without material impetus, as a loadstone attracts. But a loadstone seems even to repel loadstone. For the pole of one loadstone repels the pole of another, which does not agree with it according to nature; by repelling, it turns it round in an orbit so that they may exactly agree according to their nature. But if a somewhat weak loadstone, floating freely on water, cannot readily be turned round on account of impediments, the whole loadstone is repelled and sent further away from the other. All electricks attract all things: they never repel or propel anything at all[194]. As to what is related about certain plants (as about the cucumber, which turns aside when oil is applied to it), there is a material change from the vicinity, not a hidden antipathy. But when they show a candle flame put against a cold solid substance (as iron) turn away to the side, and allege antipathy as the cause, they say nothing. The reason of this they will see clearer than the day, when we discourse on what heat is[195]. But Fracastorio's opinion that a loadstone can be found, which would drive iron away, on account of some opposing principle lurking in the iron, is foolish.

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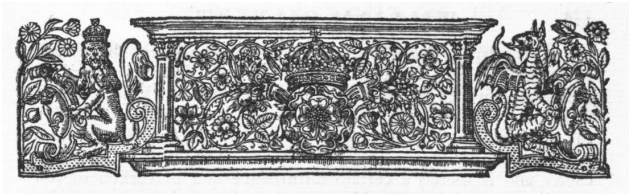


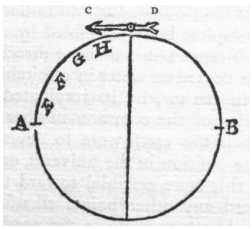
BOOK THIRD.

CHAP. I.

ON DIRECTION.

On referring to the earlier books it will be found shown that a loadstone has its poles, and that a piece of iron has also poles, and rotation, and a certain verticity; finally, that the loadstone and the iron direct their poles toward the poles of the earth. Now, however, we must make clear the causes of these things and their admirable workings, pointed out indeed before, but not proven. All those who have written before us about these rotations have left us their opinions so briefly, so meagrely, and with such hesitating judgment that they seem hardly likely ever to persuade anyone, or even to be able to satisfy themselves; and all their petty reasons are rejected by the more prudent as useless, uncertain, and absurd, being supported by no proofs or arguments; whence also magnetick science, being all the more neglected and not understood, has been in exile. The true austral pole of a loadstone, * not the boreal (as all before us used to think), if the loadstone is placed in its boat on the surface of water, turns to the North; in the case of a piece of iron also, whether it has been excited by a loadstone or not, the southern end moves toward the North. An oblong piece of iron of three or four digits' length[196], when skilfully rubbed with a loadstone, quickly turns north and south. Wherefore mechanicians, taking a piece of iron prepared in this way, balance it on a pin in a box, and fit it up with the requisites of a sun-dial; or they prepare the versorium out of two curved pieces of iron with their ends touching one another, so that the motion may be more constant. In this way the mariners' versorium is arranged, which is an instrument beneficial, useful, and

auspicious to sailors for indicating, like a good genius, safety and the right way. But it must be understood on the threshold of this argument (before we proceed further) that these pointings of the loadstone or of iron are not perpetually made toward the true poles of the world, do not {116} always seek those fixed and definite points, or remain on the line of the true meridian; but usually diverge some distance to the East or to the West. Sometimes also at certain places on land or sea they do indicate exactly the true poles. This discrepancy is called the *Variation* of the iron or of the loadstone; and since this is brought about by other causes, and is merely a certain disturbance and perversion of the true direction, we are directing our attention in this place to the true direction of the compass and of the magnetick iron (which would be equally toward the true poles and on the true meridian everywhere on the earth, unless other obstacles and an untoward pervertency hindered it). Of its variation and the cause of the perversion we shall treat in the next book. Those who wrote about the world and about natural philosophy a century ago, especially those remarkable elementary philosophers, and all those who trace their knowledge and training to them down to our own times, those men, I say, who represented the earth as always at rest and, as it were, a useless weight, placed in the centre of the universe at an equal distance from the sky on every side, and its nature to be simple, imbued only with the qualities of dryness and cold, sought diligently for the causes of all things and of all effects in the heavens, the stars, the planets, in fire, air, waters and substances of mixed natures. Never indeed did they recognize that the terrestrial globe had, besides dryness and cold, some special, effective, and predominant properties, strengthening, directing, and moving the globe itself through its whole mass and its very deepest vitals; nor did they ever inquire whether there were any such. For this reason the crowd of philosophizers, in order to discover the reasons of the magnetical motions, called up causes lying remote and far away. And one man seems to me beyond all others worthy of censure, Martin Cortes, who, since there was no cause which could satisfy him in the whole of nature, dreamed that there was a point of magnetical attraction beyond the heavens, which attracted iron. Peter Peregrinus thinks that the direction arises from the poles of the sky. Cardan thought that the turning of iron was caused by a star in the tail of the Great Bear; Bessard, the Frenchman, opines that a magnetick turns toward the pole of the zodiack. Marsilius Ficinus will have it that the loadstone follows its own Arctick pole; but that iron follows the loadstone, straws amber; whilst this perhaps follows the Antarctick pole—a most foolish dream. Others have recourse to I know not what magnetick rocks and mountains. Thus it is always customary with mortals, that they despise things near home, whilst foreign and distant things are dear and prized. But we study the earth itself and observe in it the cause of so great an effect. The earth, as the common mother, has these causes inclosed in her innermost parts; in accordance with her rule, position, condition, verticity, poles, æquator, horizons, meridians, centre, circumference, {117} diameter, and the nature of the whole interior of her substance, must all magnetical motions be discussed. The earth has been ordered by the highest Artificer and by nature in such a way that it should have parts dissimilar in position, bounds of the whole and complete body, ennobled by certain functions, by which it might itself remain in a definite direction. For just as a loadstone, when it is floated on water in a suitable vessel, or is hung by slender threads in the air, by its implanted verticity conforms its poles to the poles of the common mother in accordance with magnetick laws; so if the earth were to deviate from its natural direction and its true position in the universe, or if its poles were to be drawn aside (if this were possible) toward the sun-rising or the sun-setting or toward any other points whatsoever in the visible firmament, they would return again to the north and south by magnetical motion, and would settle at the same points at which they are now fixed. The reason why the terrestrial globe seems to remain more steadily with the one pole toward those parts and directed toward the Cynosure, and why its pole diverges by 23 degrees 29 minutes, with a certain variation not sufficiently investigated as yet by Astronomers, from the poles of the ecliptick, depends on its virtue magnetical. The causes of the precession of the æquinoxes and the progression of the fixed stars, and of the change, moreover, in the declinations of the sun and of the tropicks, must be sought from magnetick influences; so that neither that absurd motion of trepidation of Thebit Bencora[197], which is at great variance with observations, nor the monstrous superstructures of other heavens, are any longer needed. A versatory iron turns to the position of the earth, and if disturbed ever so often returns always to the same points. For in the far regions of the north, in a latitude of 70 or 80 degrees (to which at the milder seasons of the year our sailors are accustomed to penetrate without injury from the cold); in the regions halfway between the poles; on the æquator in the torrid zone; and again in all the maritime places and lands of the south, in the highest latitude which has thus far been reached, always the iron magnetick finds its way, and points to the poles in the same manner (excepting for the difference of variation); on this side of the æquator (where we live), and on the other side to the south, less well known, but yet in some measure explored by sailors: and always the lily of the compass points toward the North. This we have had confirmed by the most eminent captains, and also by very many of the more intelligent sailors. These facts have been pointed out to me and confirmed by our most illustrious Sea-god, Francis Drake, and by another circumnavigator of the globe, Thomas Candish; our terrella also indicates the same thing. This is demonstrated in the case of the orbicular stone, whose poles are A and B; {118}



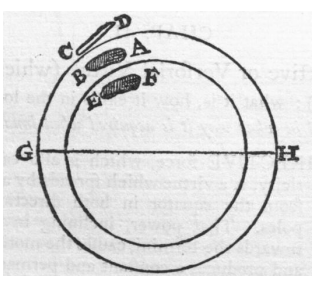
an iron wire CD, which is placed upon the stone, always points directly along the meridian toward the poles AB, whether the centre of the wire is on the central line or æquator of the stone, or on any other part situated between the æquator and the poles, as at H, G, F, E. So the cusp of a * versorium on this side of the æquator points toward the north; on the other side the cross is always directed toward the south; but the cusp or lily[198] does not, as some one has thought, turn toward the south beyond the æquator. Some inexperienced people indeed, who in distant parts

beyond the æquator have seen the versorium sometimes become more sluggish and less prompt, thought that the distance from the arctick pole or from the magnetick rocks was the cause of this. But they are very much mistaken; for it is as powerful[199], and adjusts itself as quickly to the meridian or to the point of variation in the southern as in the northern parts of the earth. Yet sometimes the motion appears slower, namely, when the supporting pin by lapse of time and long voyaging has become somewhat blunt, or the magnetick iron parts have lost, by age or rust, some of their acquired vigour. This may also be shown experimentally by the versatory iron of a small sun-dial placed on a very short pin set perpendicular to the surface of the stone, for the iron when touched by a loadstone points toward the poles of the stone and leaves the poles of the earth; for the general and remoter cause is overcome by the particular and powerful cause which is so near at hand. Magnetick bodies have of themselves an inclination toward the position of the earth and are influenced by a terrella. Two equal stones of equal strength adjust themselves to a terrella in accordance with magnetick laws. The iron conceives vigour from the loadstone and is influenced by the magnetical motions. Wherefore true direction is the motion of a magnetick body in regard to the verticity of the earth, the natures of both agreeing and working together toward a natural position and unity. For indeed we have found out at length, by many experiments and in many ways, that there is a disposing nature, moving them together by reason of their various positions by one form that is common to both, and that in all magnetick {119} substances there is attraction and repulsion. For both the stone[200] and the magnetick iron arrange themselves by inclination and declination, according to the common position of their nature and the earth. And the force of the earth by the virtue of the whole, by attracting toward the poles, and repelling, arranges all magneticks which are unfixed and loose. For in all cases all magneticks conform themselves to the globe of the earth in the same ways and by the same laws by which another loadstone or any magneticks do to a terrella.[201]

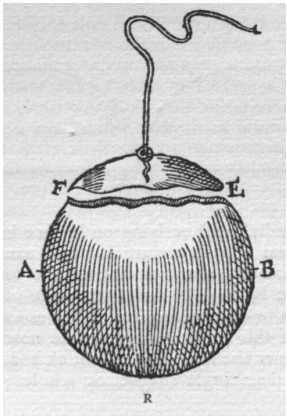
CHAP. II.

The Directive or Versorial Virtue (which we call verticity): what it is, how it exists in the loadstone; *and in what way it is acquired when innate.*

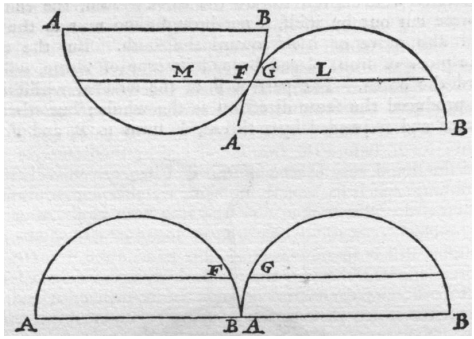
Directive force, which is also called by us verticity, is a virtue which spreads by an innate vigour from the æquator in both directions toward the poles. That power, inclining in both directions towards the termini, causes the motion of direction, and produces a constant and permanent position in Nature, not only in the earth itself but also in all magneticks. Loadstone is found either in veins of its own or in iron mines, when the homogeneous substance of the earth, either having or assuming a primary form, is changed or concreted into a stony substance, which besides the primary qualities of its nature has various dissimilitudes and differences in different quarries and mines, as if from different matrices, and very many secondary qualities and varieties in its substance. A loadstone which is dug out in this breaking up of the earth's surface and of protuberances upon it, whether formed complete in itself (as sometimes in China) or in a larger vein, is fashioned by the earth and follows the nature of the whole. All the interior parts of the earth mutually conspire together in combination and produce direction toward north and south. But those magnetical bodies which come together in the uppermost parts of the earth are not true united parts of the whole, but appendages and parts joined on, imitating the nature of the whole; wherefore when floating free on water, they dispose themselves just in the same way as they are placed in the terrestrial * system of nature. We had a large loadstone of twenty pounds weight, dug up and cut out of its vein, after we had first observed and marked its ends; then after it was dug out, we placed it in a boat on water, so that it could turn freely; then immediately the face which had looked toward the north in the quarry began to turn to the north on the waves and at length settled toward that {120} point. For that face which looked toward the north in the quarry is the southern, and is attracted by the northern parts of the earth, in the same way as pieces of iron which acquire their verticity from the earth. About this point we intend to speak afterwards[202] under change of verticity. But there is a different rotation of the internal parts of the earth, which are perfectly united to the earth and which are not separated from the true substance of the earth by the interposition of bodies as are loadstones in the upper portion of the earth, which is maimed, corrupt, and variable. Let A B be a piece of magnetick ore; between which and the uniform globe of the earth lie various soils or mixtures which separate the ore to a certain extent from the globe of the true earth. It is therefore influenced by the forces of the earth just in the same way as C D, a piece of iron, in the air. So the face B of some ore or of that piece of it is moved toward the Boreal pole G, just as the extremity C of the iron, not A or D. But the condition of the piece E F is different, which piece is produced in one connected mass with the whole, and is not separated from it by any earthy mixture. For if the part E F were taken out and floated freely in a boat by itself, it is not E that would be directed toward the Boreal pole, but F. So in those substances which acquire their verticity in the air, C is the southern part and is seen to be attracted by the Boreal pole G. In the case of others which are found in the upper unstable portion of the earth, B is the south, and in like manner inclines toward the Boreal pole. But if



those pieces deep down which are produced along with the earth are dug up, they turn about on
* a different plan. For F turns toward the Boreal parts of the earth, because is the southern part; E toward the south, because it is the northern. So of a magnetick body, C D, placed close to the earth, the end C turns toward the Boreal pole; of one that is adnate to it B A, B inclines to the North; of one that is innate in it, E F, E turns toward the southern pole; which is confirmed by the following demonstration, and comes about of necessity according to all {121}
magnetick laws. Let there be a terrella with poles A B; from its mass cut out a small part E F; if this be suspended by a fine thread above the hole or over some other place, E does not seek the pole A but the pole B, and F turns to A; very differently from a rod of iron C D; because C, touching some northern part of the terrella, being magnetically carried away makes a turn round to A, not to B. And yet here it should be observed, that if the
* pole A of the terrella were moved toward the earth's south, the end E of the piece cut out by itself, if not brought too near to the stone, would also move of itself toward the south. But the end C of the piece of iron, placed beyond its orbe of virtue, will turn toward the north. The part E F of the terrella, whilst in the mass, produced the same direction as the whole; but when it is separated and suspended by a



thread, E turns to B, and F to A. So parts having the same verticity with {122}
the whole, when separated, are impelled in the contrary direction; for contrary parts solicit contrary parts. Nor yet is this a true contrariety, but the highest concordancy, and the true and genuine conformation of bodies magnetical in the system of nature, if they shall have been divided and separated: for the parts thus divided should be raised some distance from the whole, as will be made clear afterwards. Magnetick substances seek a unity as regards form; they do not so much respect their own mass. Wherefore the part F E is not attracted into its former
* bed; but when once it is unsettled and at a distance, it is solicited by the opposite pole. But if the small piece F E is placed back again in its bed or brought close to, without any substances intervening, it acquires its former combination, and, as a part of the whole once more united, accords with the whole and sticks readily in its former position; and E remains toward A, and F toward B, and they settle steadily in their mother's lap. The reasoning is the same when the stone is divided into equal parts through the poles. A spherical stone is



* divided into two equal parts along the axis A B; whether therefore the surface A B is in the one part facing upward (as in the former diagram) or lying on its face in
* both parts (as in the latter), the end A tends toward B. But it must also be understood that the point A is not carried with a definite aim always toward the point B, because in consequence of the division the verticity proceeds to other points, as to F G, as appears in the fourteenth chapter of this book. And L M are now the axes in each, and A B is no longer the axis; for magnetick bodies, as soon as they are divided, become single magnetick wholes; and they have vertices in accordance {123}
with their mass, new poles arising at each end in consequence of the division. Yet the axis and the poles always follow the leading of a meridian; because that force passes along the meridians of the stone from the æquator to the poles, by an everlasting rule, the inborn virtue of the substance agreeing thereto from the long and lasting position and the facing of a suitable substance toward the poles of the earth; by whose strength continued through many centuries it has been fashioned; toward fixed and determined parts of which it has remained since its origin firmly and constantly turned.

CHAP. III.

How Iron acquires Verticity through a Loadstone, and how that verticity *is lost and changed.*

riction between an oblong piece of iron and a loadstone imparts to the former magnetick virtues, which are not corporeal nor inherent and persistent in any body, as we showed in the discussion on coition. It is plain that the iron, when it has been rubbed hard with one end and applied to the stone for a pretty long time, receives no stony nature, acquires no weight; for if, before the iron is touched by the stone, you
* weigh it in a small and very exact goldsmith's balance, you will see after the rubbing that it has exactly the same weight, neither diminished nor increased. But if you wipe the iron with cloths after it has been touched, or wash it in water, or scour it with sand or on a grindstone, still it in nowise lays aside its acquired strength. For the force is spread through the whole body and conceived in the inmost parts, and cannot in any way be washed or wiped away. Let an experiment then be made in fire, that untamed tyrant of nature. Take a piece of iron of the

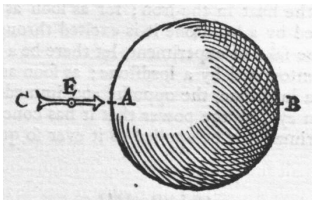
length of a palm and the thickness of a goosequill pen; let this iron be passed through a suitable round cork and placed on the surface of water, and observe the end which turns to the north; rub this particular end with the true southern end of a loadstone; the iron so rubbed turns toward the
* south. Remove the cork, and place the end which was excited in the fire until the iron is just red-hot; when it is cooled, it will retain the strength of the loadstone and the verticity, though it will not be so prompt, whether because the force of the fire had not yet continued long enough to overcome all its strength, or because the whole iron was not heated to redness, for the virtue is {124}
diffused through the whole. Remove the cork a second time, and putting the whole iron in the fire, blow the fire with the bellows, so that it may be all aglow, and let it remain a little longer time red-hot; when cooled (so, however, that, whilst it is cooling, it does not rest in one position),
* place it again on the water with the cork, and you will see that it has lost the verticity which it had acquired from the stone. From these experiments it is clear how difficult it is for the property of polarity implanted by the loadstone to be destroyed. But if a small loadstone had remained as long in the same fire, it would have lost its strength. Iron, because it does not so easily perish, and is not so easily burnt up as very many loadstones, retains its strength more stably, and when it is lost can recover it again from a loadstone; but a loadstone when burnt does not revive. But
* now that iron, which has been deprived of its magnetick form, moves in a different way from any other piece of iron, for it has lost its polar nature; and whereas before the touch of the loadstone it may have had a motion toward the north, and after contact toward the south; now it turns to no
* definite and particular point; but afterwards, very slowly and after a long time, it begins to turn in a doubtful fashion toward the poles of the earth (having acquired some power from the earth). I have said that the cause of direction was twofold, one implanted in the stone and iron, but the other in the earth, implanted by the disponent virtue; and for that reason (the distinction of poles and the verticity in the iron having now been destroyed) a slow and weak directive power is acquired anew from the verticity of the earth. We may see, therefore, with what difficulty and only by the application of hot fires and by long ignition of the iron heated to softness, the imparted magnetick virtue is eradicated. When this ignition has overcome the acquired polarity, and it has been now completely subdued and not awakened again, that iron is left unsettled and utterly incapable of direction. But we must further inquire how iron remains affected by verticity. It is manifest that it strongly affects and changes the nature of the iron, because the presence of a loadstone attracts the iron to itself with an altogether wonderful readiness. Nor is it only the part that is rubbed, but on account of the rubbing (on one end only) the whole iron is affected together, and gains by it a permanent though an unequal power. This is demonstrated as follows.
* Rub an iron wire on the end so that it is excited, and it will turn towards the north; afterward cut off some portion of it; you will see that it still turns toward the north (as before), but more feebly. For it must be understood that the loadstone excites a steady verticity in the whole iron (if the rod be not too long) more vigorous throughout the whole mass in a shorter bar, and as long as the iron remains touching the loadstone a little stronger. But when the iron is separated from {125}
contact with it, then it becomes much weaker, especially in the end that was not touched. Just as a long rod, one end of which is placed in the fire and heated, grows exceedingly hot at that end, less so in the parts adjoining and in the middle, whilst at the other end it can be held in the hand, and that end is only warm; so the magnetical vigour diminishes from the excited end to the other end; but it is present there instantly, and does not enter after an interval of time nor successively, as the heat in the iron; for as soon as a piece of iron has been touched by a loadstone it is excited
* throughout its whole length. For the sake of experiment, let there be a rod of iron 4 or 5 digits long, untouched by a loadstone; as soon as you touch one end only with a loadstone, the opposite end immediately, or in the twinkling of an eye, by the power that it has conceived, repels or attracts a versorium, if it be applied to it ever so quickly.

CHAP. IIII.

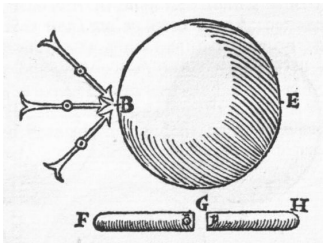
Why Iron touched by a Loadstone acquires an opposite *verticity, and why iron touched by the true Northern side of a stone* turns to the North of the earth, by the true Southern side *to the South; and does not turn to the South when rubbed by the Northern point of the stone, and when by the Southern to the North, as all who have written on the loadstone have falsely supposed.*

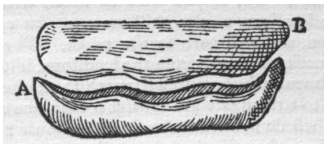
emonstration has already been given that the northern part of a loadstone does not attract the northern part of another stone, but the southern, and repels the northern part of another stone from its northern side when it is applied[203] to it. That general magnet, the terrestrial globe, disposes iron touched by a loadstone in the same way, and likewise magnetick iron stirs this same iron by its implanted strength, and excites motion and controls it. For whether the comparison and experiment has been made between loadstone and loadstone, or loadstone and iron, or iron and iron, or the earth and loadstone, or
* the earth and iron conformed by the earth or strengthened by the power of a loadstone, the strength and inclinations of each must mutually harmonize and accord in the same way. But the reason must be sought, why a piece of iron when touched by a loadstone acquires a disposition to

motion toward the opposite pole of the earth, and not toward that pole of the earth to which that {126}
pole of that loadstone turned by which it was excited. It has been pointed out that iron and loadstone are of one primary nature; when the iron is joined to the loadstone, they become, as it were, one body, and not only is the end of the iron changed, but the remaining parts also are affected along with it. A, the north pole of a loadstone, is placed against the cusp of a piece of iron; the cusp of the iron has now become the southern part of the iron, because it is touching the northern part of the stone; the cross-end of the iron has become the northern. For if that contiguous magnetick substance be separated from the pole of the terrella, or from the parts near the pole, the one end (or the end which, whilst the connection was kept up, was touching the northern part of the stone) is the southern, whilst the other is the northern. So also if a versorium excited by a loadstone be divided into ever so many parts (however small), those parts when separated will, it is clear, arrange themselves in the same disposition as that in which they were disposed before, when they were undivided. Wherefore whilst the cusp remains over the northern pole A, it is not the southern end, but is, as it were, part of a whole; but when it is taken away from the stone, it is the southern end, because when rubbed it tended toward the northern parts of the stone, and the cross (the other end of the versorium) is the northern end. The loadstone and the iron make one body; B is the south pole of the whole; C (that is, the cross) is the northern end of the whole; divide the iron also at E, and E will be the southern end with respect to the cross; and E will likewise be the northern end in respect to B. A is the true northern pole of the stone and is attracted by the southern pole of the earth. The end of the iron which is touched by the true boreal part of the stone becomes the southern end, and turns to A, the north [pole] of the stone, if it be near; or if it be some distance from the stone it turns to the north [pole] of the earth. So always iron which is touched (if it is free and unrestrained) tends to the opposite part of the earth

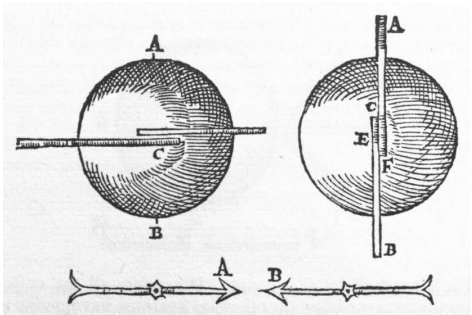


* from that part to which the loadstone that touched it tends. Nor does it make any difference how it is rubbed, whether straight up or slanting in some way. For in any case the verticity flows into the iron, provided it is touched by either end. Wherefore all the {127}
cusps at B acquire the same verticity, after they are separated, but opposite to that pole of the stone; wherefore also they are united to the loadstone at the pole B; and all the crosses in the present figure have the opposite verticity to the pole E, and are moved and laid hold of by E when they are in a convenient position. It is exactly the same in the case of the long stone F H divided at G; F and H always move, both in the whole and in the divided stone, to opposite poles of the earth, and O and P mutually attract one another, the one of them being the northern, the other the southern. For, supposing H to have been the southern in the whole stone and F the northern, P will be the northern with respect to H in the divided stone, and O the southern with respect to F. So also F and H mutually incline to a connection, if they are turned a very little toward one another, and run together at length and join. But supposing the division of the stone to have been meridional (that is, according to the line of a meridian, not of any parallel circle), then they turn round, and A attracts B, and the end B is attracted to A and attracts A, until, being turned round, they are connected and cemented together; because magnetick attraction is not made along the parallels, but meridionally. For this reason pieces of iron placed on a terrella



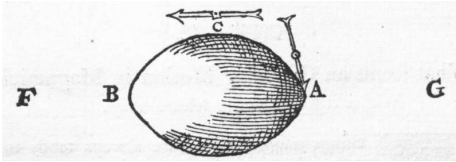


* whose poles are A B, near the æquator along parallels, do not combine or stick together firmly: But if applied to one another along {128}
* a meridian they are immediately joined firmly together, not only on and near the stone, but even at some distance within the force of the controlling orbe. Thus they are joined and cemented together at E, but not at C in the other figure. For the opposite ends C and F meet and adhære together in the case of the iron just in the same way as A and B before in the case of the stone. But they are opposite ends, because the pieces of iron proceed from the opposite sides and poles of the terrella; and C in reference to the northern pole A is southern, and F is boreal in reference to the southern pole B. In like manner also they are cemented together, if the rod C (being not too long[204]) be moved further toward A, and F toward B, and they be joined together over the terrella, like A and B of the divided stone above.



* But now if the cusp A, which has been touched by a loadstone, be the southern end, and you were to touch and rub with this the cusp of another iron needle B, which has not been touched, B will be northern, and will point to the south. But if you were to touch with the northern point B any other iron needle, still new, on its cusp, this again will be southern, and will turn to the north. The iron not only receives the necessary strength from the loadstone, if it be a good loadstone, but also imparts its acquired strength to another piece of iron, and the second to a third (always in strict accordance with magnetick laws). In all these demonstrations of ours it should always be borne in mind that the poles of a stone, as well as those of iron, whether touched or untouched, are always in fact and by nature opposite to the pole toward which they point and are so
* designated by us, as we have laid down above. For in them all it is always the northern which tends to the south, either of the earth or of the stone, and the southern which tends to the north

of the stone. Northern parts are attracted by the southern of the earth; so in the boat they tend toward the south. A piece of iron touched by the northern parts of a loadstone becomes south at the one end and tends always (if it is near and within the orbe of the loadstone) to the north of the stone, and if it be free and left to itself at some distance from the stone, it tends to the northern part of the earth. The northern pole A of a loadstone turns to G, the south of the earth; a versorium touched at its cusp by the part A follows A, because it has become southern. But the versorium C, placed farther away from the loadstone, turns its cusp to F, the north of the earth, {129}
* because the cusp has become southern by contact with the boreal part of the stone. So the ends touched by the northern part of the stone are made southern, or are excited with a southern polarity, and tend toward the north of the earth; those touched by the southern pole are made northern, or are excited with a northern force, and turn to the south of the earth.



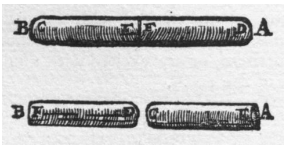
CHAP. V.

On the Touching of pieces of Iron
of divers shapes.

Bars of iron, when touched by a loadstone, have one end north, the other south, and in
* the middle is the limit of verticity, like the æquinoctial circle on the globe of a terrella or on an iron globe. But when an iron ring is rubbed on one side on a loadstone, then the one pole is on the place that was in contact, whilst the other is at the opposite point; and the magnetick power divides the ring into two parts by a natural distinction which, though not in shape, yet in power and effect is like an æquator. But if a thin straight rod be bent into a ring without any welding or union of the ends, and be touched in the middle by a loadstone, both ends will be of the same verticity. Let a ring be taken which is whole and
* continuous, and which has been touched by a loadstone at one place, and let it be divided
* afterward at the opposite point and straightened out, both ends will also be of the same verticity, {130}
no otherwise than a thin rod touched in the middle or a ring not cohærent at the joint.

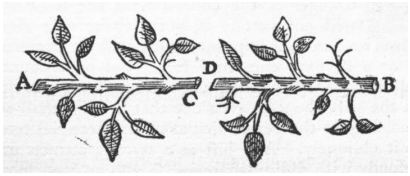
CHAP. VI.

What seems an Opposing Motion in Magneticks
is a proper motion toward unity.



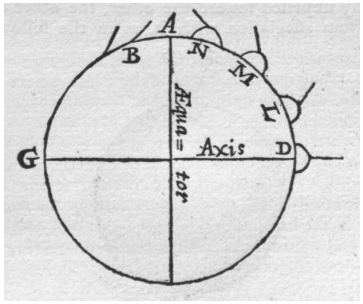
In things magnetical nature always tends to unity, not merely to confluence and agglomeration, but to harmony; in such a way that the rotational and disponent faculty should not be disturbed, as is variously shown in the following example. Let C D be an entire body of some magnetick substance, in which C tends to B, the north of the earth, and D to the south, A. Then[205] divide it in the middle in its æquator, and it will be E that is tending toward A, and F tending toward B. For just as in the undivided body, so in the divided, nature aims at these bodies being united; the end E again joins with F harmoniously
* and eagerly and they stick together, but E is never joined to D, nor F to C; for then C must be turned contrary to nature toward A, the south, or D toward B, the north, which is foreign to them and incongruous. Separate the stone in the place where it is cut and turn D round to C; they harmonize and combine excellently. For D is tending to the south, as before, and C to the north; E and F, parts which were cognate in the ore, are now widely separated, for they do not move together on account of material affinity, but they take their motion and inclination from their form. So the ends, whether joined or divided, tend magnetically in the same way to the earth's poles in the first figure where there is one whole, or divided as in the second figure; and F E in the second figure is a perfect magnetick joined together into one body and C D, just as it was primarily produced in its ore, and F E in its boat, turn in this way to the poles of the earth and {131}
* are conformed to them. This harmony of the magnetick form is shown also in the forms of
* vegetables. Let A B be a twig from a branch of osier or other tree which sprouts easily. Let A be the upper part, B the lower part toward the root; divide it at C D; I say that the end D, if grafted

again to C by the primer's art, grows to it; just as also if B is grafted to A, they grow together and germinate. But D being grafted on A, or C on B, they are at variance, and never grow into one another, but one of them dies on account of the inverted and inharmonious arrangement, since the vegetative force, which moves in one way, is now impelled in opposite directions.



CHAP. VII.

A determined Verticity and a disponent Faculty are what arrange magneticks, not a force, attracting or pulling them *together, nor merely strongish coition or unition.*



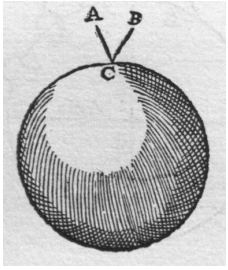
In the neighbourhood of the æquinoctial A there is no coition of the ends of a piece of iron with the terrella; at the poles there is the strongest. The greater the distance from the æquinoctial, the stronger is the coition with the stone itself, and with any part of it, not with its pole alone. Yet pieces of iron are not raised up on account of some peculiar attracting force or a stronger combined force, but on account of that common directing or conforming and rotating force; nor indeed is a spike in the part about B, even one {132}
* that is very small and of no weight[206], raised up to the perpendicular by the strongest terrella, but cleaves to it obliquely. Also just as a terrella attracts magnetick bodies variously with dissimilar forces, so also an iron snout placed on the stone obtains a different potency in
* proportion to the latitude, just as a snout at L by its firmer connection resists a greater weight more stoutly than one at M, and at M than at N. But neither does the snout raise the spike to the perpendicular except at the poles, as is shown in the figure. A snout at L may hold and lift from the earth two ounces of iron in one piece; yet it is not strong enough to raise an iron wire of two grains weight to the perpendicular, which would happen if the verticity arose on account of a
* stronger attraction, or rather coition or unition.

CHAP. VIII.

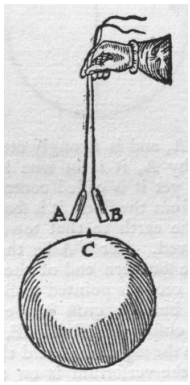
Of Discords between pieces of Iron upon the same pole of a loadstone, and how they can agree and *stand joined together.*

* Suppose two iron wires or a pair of needles stuck on the pole of a terrella; though they ought to stand perpendicularly, they mutually repel one another at the upper end, and produce the appearance of a fork; and if one end be forcibly impelled toward the other, the other declines and bends away from association with it, as in the following figure.

A and B, iron spikes, adhære obliquely[207] upon the pole on account of their nearness to one another; either alone would otherwise stand erect and perpendicular. For the extremities A B, being of the same verticity, mutually abhor and fly one another. For if C be the northern pole of the terrella, A and B are also northern ends; but the ends which are joined to {133}
* and held at the pole C are both southern. But if those spikes be a little longer (as, for example, of two digits length) and be joined by force, they adhære together and unite in a friendly style, and are not separated without force. For they are magnetically welded, and there are now no longer two distinct ends, but one end and one body; no less than a wire which is



doubled and set up perpendicularly. But here is seen also another subtile point, that if those
* spikes were shorter, not as much as the breadth of one digit, or even the length of a barleycorn, they are in no way willing to harmonize or to stand straight up at the same time, because naturally in shorter wires the verticity is stronger in the ends which are distant from the terrella and the magnetick discord more vehement than in long ones. Wherefore they in no way admit of an intimate association and connection.



Likewise if those lighter pieces of iron or iron wires be suspended, hanging, as A and B, from a
* very fine silk thread, not twisted but braided, distant from the stone the length of a single barleycorn, then the opposing ends, A and B, being situated within the orbe of virtue above the pole, keep a little away from one another for the same reason; except when they are very near the pole of the stone C, the stone then attracting them more strongly toward one end.

CHAP. IX.

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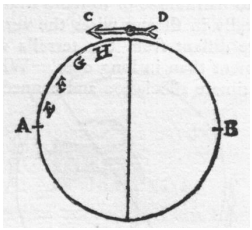
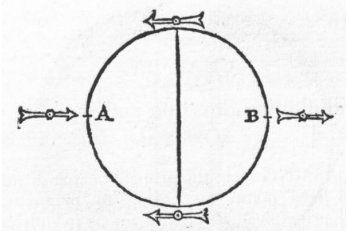
Figures illustrating direction and showing varieties *of rotations.*

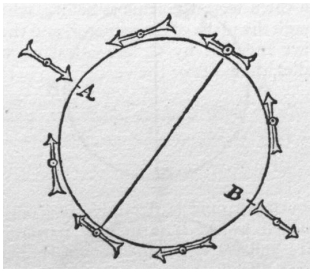


Passing from the probable cause of motion toward fixed points (according to magnetick laws and principles), it remains for us to indicate those motions. Above a round loadstone (whose poles are A, B) let a versatory needle be placed whose cusp has been excited by the pole A; that cusp is certainly directed toward A, and is strongly attracted by A; because, having been touched by A, it is in true harmony with A, and combines with it; and yet it is called contrary, because when the versorium is separated from the stone, it is seen to be moved toward the opposite part of the earth to that toward which the pole A of the loadstone is moved. For if A be the northern pole of the terrella, the cusp is the southern end of the needle, of which the other end (namely, the cross) is pointed to B; so B is the southern pole of the loadstone, but the cross is the northern end
* of the versorium. So also the cusp is attracted by E, F, G, H, and by every part of a meridian, from the æquator toward the pole, by the faculty disponent; and when the versorium is on the same parts of the meridian, the cusp is directed toward A. For it is not the point A that turns the versorium toward it, but the whole loadstone; as also the whole earth does, in the turning of loadstones to the earth.

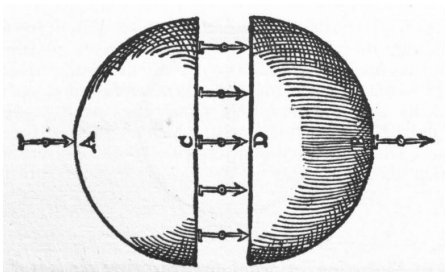


Figures illustrating magnetick directions in a right sphere[208] *of stone, and in the right sphere of the earth, as well as the polar directions to the perpendicular of the poles.* All these cusps have been touched by the pole A; all the cusps are turned toward A, excepting that one which is repelled by B.

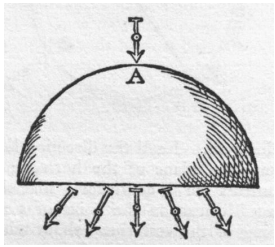
{135}



Figures illustrating horizontal directions above the body of a loadstone. All the cusps that have been made southern by rubbing on the boreal pole, or some place round the northern pole A, turn toward the pole A, and turn away from the southern pole B, toward which all the crosses look. I call the direction horizontal, because it is arranged along the plane of the horizon; for
* nautical and horological instruments are so constructed that the iron hangs or is supported in æquilibrium on the point of a sharp pin, which prevents the dipping of the versorium, about which we intend to speak later. And in this way it is of the greatest use to man, indicating and distinguishing all the points of the horizon and the winds. Otherwise on every oblique sphere (whether of stone or the earth) versoria and all magnetick substances would have a dip by their own nature below the horizon; and at the poles the directions would be perpendicular, which appears in our discussion *On Declination*.



A round stone (or terrella) cut in two at the æquator; and all the cusps have been touched by the pole A. The points at the centre of the earth, and between the two parts of the terrella which has been cut in two through the plane of the æquator, are directed as in the present[209] diagram. {136}
This would also happen in the same way if the division of the stone were through the plane of a tropick, and the mutual separation of the divided parts and the interval between them were the same as before, when the loadstone was divided through the plane of the æquator, and the parts separated. For the cusps are repelled by C, are attracted by D; and the versoria are parallel, the poles or the verticity in both ends mutually requiring it.



* *Half a terrella by itself and its directions, unlike the directions of the two parts close to one another as shown in the figure above*. All the cusps have been touched by A; all the crosses below except the middle one tend toward the loadstone, not straight, but obliquely; because the pole is in the middle of the plane which before was the plane of the æquator. All cusps touched by places distant from the pole move toward the pole (exactly the same as if they had been rubbed upon the pole itself), not toward the place where they were rubbed, wherever that may have been in the undivided stone in some latitude between the pole and the æquator. And for this reason there are only two distinctions of regions, northern and southern, in the terrella, just as in the general {137}
terrestrial globe, and there is no eastern nor western place; nor are there any eastern or western regions, rightly speaking; but they are names used in respect of one another toward the eastern or western part of the sky. Wherefore it does not appear that Ptolemy did rightly in his *Quadripartitum*, making eastern and western districts and provinces, with which he improperly connects the planets, whom the common crowd of philosophizers and the superstitious soothsayers follow.

CHAP. X.

On Mutation of Verticity and of Magnetick

Properties, or on alteration in the power
excited by a loadstone.

 riction with a loadstone gives to a piece of iron a verticity strong enough; not, however, so stable that the iron may not by being rubbed on the opposite part (not only with a more powerful loadstone, but with the same) be changed and deprived of all its former verticity, and indued with a new and opposite one. Take a piece of iron wire and rub each end of the wire equally with one and the same pole of a loadstone, and let it be passed through a suitable cork and place it on water. Then truly one end of the wire will be directed toward that pole of the earth toward which that end of the stone will not turn. But which end of the iron wire will it be? That certainly which was rubbed last. Rub the
* other end of this again with the same pole, and immediately that end will turn itself in the opposite direction. Again touch the former end of the iron wire only with the same pole of the loadstone as before; and that[210] end, having gained the command, immediately changes to the contrary side. So you will be able to change the property of the iron frequently, and that end of the wire rules which has been touched the last. Now then merely hold the boreal pole of the stone for some time near the boreal part of the wire which was last touched, so that it does not touch, but so that it is removed from it by one, two, or even three digits, if the stone have been
* pretty strong; and again it will change its property and will turn round to the contrary side; which will also happen (albeit rather more feebly) even if the loadstone be removed to a distance of four digits. You will be able to do the same thing, moreover, with both the austral and the boreal part of the stone in all these experiments. Verticity may likewise be acquired and changed when thin
* plates of gold, silver, and glass are interposed between the stone and the end of the iron or iron wire, if the stone were rather strong, even if the intermediate lamina is not touched either by the {138}
iron or the stone. And these changes of verticity take place in smelted iron. Indeed what the one pole of the stone implants and excites, the other disturbs and extinguishes, and confers a new force. For it does not require a stronger loadstone to take away the weaker and sluggish virtue and to implant the new one; nor is iron inebriated by the equal strength of loadstones, and made utterly uncertain and neutral, as Baptista Porta teaches; but by one and the same loadstone, or by loadstones endowed with equal power and might, its strength is, in accordance with magnetick rules, turned round and changed, excited, repaired, or disturbed. But a loadstone itself, by being rubbed on another, whether a larger or a more powerful stone, is not disturbed from its own property and verticity, nor does it turn round toward the opposite direction in its boat, or to the other pole opposite to that to which it inclines by its own nature and implanted verticity. For strength which is innate and has been implanted for a very long time abides more firmly, nor does it easily yield from its ancient holding; and that which has grown for a long time is not all of a sudden brought to nothing, without the destruction of the substance containing it.
* Nevertheless in a long interval of time a change does take place; in one year, that is to say, or two, or sometimes in a few months; doubtless when a weaker loadstone remains lying by a stronger one contrary to the order of nature, namely, with the northern pole of one loadstone adjoined to the northern pole of another, or the southern to the southern. For so the weaker strength gradually declines with the lapse of time.

CHAP. XI.

On the Rubbing of a piece of Iron on a Loadstone
in places midway between the poles, and upon
the æquinoctial of a terrella.

 elect a piece of iron wire of three digits length, not touched by a loadstone (but it will be better if its acquired verticity be rather weak or have been damaged in some way); touch it and rub it on the æquator of a terrella, exactly on the æquinoctial line in the direction of its length, on the one end, or the ends only, or in all its parts; place the
* wire touched in this way on water in a cork fitted for it; it will swim about doubtfully on the waves without any acquired verticity, and the verticity previously implanted will be disturbed. If, however, it float by chance toward the poles, it will be checked a little by the poles of the earth, and will at length by the influence of the earth be indued with verticity.

CHAP. XII. {139}

In what way Verticity exists in any Iron that has
been smelted though not excited by a lodestone.

Having thus far[211] demonstrated natural and inborn causes and powers acquired by means of the stone, we will now examine the causes of magnetick virtues in smelted iron that has not been excited by a stone. Loadstone and iron furnish and exhibit to us wonderful subtilities. It has been repeatedly shown above that iron not excited by a stone turns north and south; further that it has verticity, that is, special and peculiar polar distinctions, just as a loadstone, or iron which has been rubbed upon a loadstone. This indeed seemed to us at first wonderful and incredible; the metal of iron from the mine is smelted in the furnace; it runs out of the furnace, and hardens into a great mass; this mass is divided in great worksteads, and is drawn into iron bars, from which smiths again construct many instruments and necessary pieces of iron-work. Thus the same mass is variously worked up and transformed into very many similitudes. What is it, then, which preserves its verticity, and {140}
whence is it derived? So take this first from the above[212] smithy. Let the blacksmith beat out upon his anvil a glowing mass of iron of two or three ounces weight into an iron spike of the length of a span of nine inches. Let the smith be standing with his face to the north, his back to
* the south, so that the hot iron on being struck has a motion of extension to the north; and let him so complete his work with one or two heatings of the iron (if that be required); let him always, however, whilst he is striking the iron, direct and beat out the same point of it toward the north, and let him lay down that end toward the north. Let him in this way complete two, three, or more pieces of iron, nay, a hundred or four hundred; it is demonstrable that all those which are thus beaten out toward the north, and so placed whilst they are cooling, turn round on their centres; and floating pieces of iron (being transfixed, of course, through suitable corks) make a motion in the water, the determined end being toward the north. In the same way also pieces of iron acquire verticity from their direction whilst they are being beaten out and hammered or drawn
* out, as iron wires are accustomed to do toward some point of the horizon between east and south or between south and west, or in the opposite direction. Those, however, which are pointed or
* drawn out rather toward the eastern or western point, conceive hardly any verticity or a very undecided one. That verticity is especially acquired by being beaten out. But a somewhat inferior
* iron ore, in which no magnetick powers are apparent, if put in a fire (its position being observed to be toward the poles of the world or of the earth) and heated for eight or ten hours, then cooled away from the fire, in the same position towards the poles, acquires a verticity in accordance with the position of its heating and cooling. Let a rod of cast iron be heated red-hot in a strong
* fire, in which it lies meridionally (that is, along the path of a meridian circle), and let be removed from the fire and cooled, and let it return to its former temperature, remaining in the same position as before; then from this it will turn out that, if the same ends have been turned to the same poles of the earth, it will acquire verticity, and the end which looked toward the North on water with a cork before the heating, if it have been placed during the heating and cooling toward the fourth, now turns round to the south. But if perchance sometimes the rotation have been doubtful and somewhat feeble, let it be placed again in the fire, and when it is taken out at a red heat, let it be perfectly cooled toward the pole from which we desire the verticity, and the
* verticity will be acquired. Let the same rod be heated in the contrary position, and let it be placed so at a red heat it is cool; for it is from its position in cooling (by the operation of the verticity of the earth) that verticity is put into the iron, and it turns round to parts contrary to its former verticity. So the end which formerly looked toward the north now turns to the south. In {141}
accordance with these reasonings and in these ways the boreal pole of the earth gives to the end
* of a piece of iron turned toward it a southern verticity, and that end is attracted by that pole. And here it must be observed that this happens to iron not only when it is cooled in the plane of the horizon, but also at any angle to it almost up to the perpendicular toward the centre of the earth. So the heated iron conceives vigour and verticity from the earth more quickly in the course of its return to its normal state, and in its recovery, as it were (in the course of which it is
* transformed), than by its mere position alone. This is effected better and more perfectly in winter and in colder air, when the metal returns more certainly to its natural temperature, than in summer and in warm regions. Let us see also what position alone and a direction toward the poles of the earth can effect by itself without fire and heat. Iron rods which have been placed and
* fixed for a long time, twenty or more years, from south to north (as they not infrequently are fixed in buildings and across windows), those rods, I say, by that long lapse of time acquire verticity and turn round, whether hanging in the air, or floating (being placed on cork), to the

pole toward which they were pointing, and magnetically attract and repel a balanced iron magnetick; for the long continued position of the body toward the poles is of much avail. This fact (although conspicuous by manifest experiments) is confirmed by an incident related in an Italian letter[213] at the end of a book of Maestro Filippo Costa, of Mantua, *Sopra le Compositioni degli Antidoti* written in Italian, which translated runs thus: "A druggist of Mantua showed me a piece of iron entirely changed into a magnet, drawing another piece of iron in such a way that it could be compared with a loadstone. Now this piece of iron, when it had for a long time held up a brick ornament on the top of the tower of the church of St. Augustine at Rimini, had been at length bent by the force of the winds, and remained so for a period of ten years. When the monks wished to bend it back to its former shape, and had handed it over to a blacksmith, a surgeon named Maestro Giulio Caesare discovered that it was like a magnet and attracted iron." This was caused by the turning of its extremities toward the poles for so long a time. And so what has been laid down before about change of verticity should be borne in mind; how in fact the poles of iron spikes are altered, when a loadstone is placed against them only with its pole and points toward them, even at a rather long distance. Clearly it is in the same way that that large magnet also (to wit, the earth itself) affects a piece of iron and changes its verticity. For, although the iron may not touch the pole of the earth, nor any magnetick part of the earth, yet verticity is acquired and changed; not because the poles of the earth and the point itself which is 39° distant from our city {142}
of London, changes the verticity at a distance of so many miles; but because the whole magnetick earth, that which projects to a considerable height, and to which the iron is near, and that which is situated between us and the pole, and the vigour existing within the orbe of its magnetick virtue (the nature of the whole conspiring thereto), produces the verticity. For the magnetick effluence of the earth rules everywhere within the orbe of its virtue, and transforms bodies; but those things which are more similar to it, and specially connected with it by nature, it rules and controls; as loadstone and iron. Wherefore in very many matters of business and actions it is clearly not superstitious and idle to observe the positions and conditions of lands, the points of the horizon and the places of the stars. For as when a babe is brought forth into the light from its mother's womb, and acquires respiration and certain animal activities, then the planets and celestial bodies[214], according to their position in the universe, and according to that configuration which they have with regard to the horizon and the earth, instil peculiar and individual qualities into the newly born; so that piece of iron, whilst it is being formed and lengthened out, is affected by the common cause (to wit, the earth); whilst it is returning also from its heated condition to its former temperature, it is imbued with a special verticity in accord
* with its position. Rather long pieces of iron sometimes have the same verticity at each end; wherefore they have motions which are less certain and well ordered on account of their length and of the aforesaid processes, exactly as when an iron wire four feet long is rubbed at each end upon the same pole of a loadstone.

CHAP. XIII.

Why no other Body, excepting a magnetick, is imbued *with verticity by being rubbed on a loadstone; and why no* body is able to instil and excite that virtue, *unless it be a magnetick.*

Igneous substances floating on water never by their own strength turn round toward the poles of the earth, save by chance. So wires of gold, silver, brass, tin, lead, or glass, pushed through corks and floating, have no sure direction; and for this reason they do not show poles or points of variation when rubbed with a loadstone. For those things which do not of themselves incline toward the poles and obey the earth are also not ruled by the touch of a loadstone; for the magnetick vigour has no entrance into their {143}
inward parts; neither is the magnetick form received by them, nor are their forms magnetically excited; nor, if it did enter, would it effect anything, because in those bodies (mixed up with various kinds of efflorescent humours and forms, corrupted from the original property of the earth) there are no primary qualities. But those prime qualities of iron are excited by the juxtaposition of a loadstone, just as brute animals or men, when they are awakened out of sleep, move and put forth their strength. Here one must marvel at a demonstrable error of B. Porta, who, while rightly opposing a very old falsehood about the diamond, in speaking of a power contrary to that of the loadstone, introduces another still worse opinion; that forsooth iron, when touched by a diamond, turns to the north. "If" (he says) "you rub a steel-Needle on a Diamond, and then put it in a Boat, or thrust it through a reed, or hang it up by a Thread, it will presently turn to the North, almost as well as if it had been touched with the Loadstone; but something more faintly. And, what is worth noting, the contrary part will turn the iron to the South: and when I had tried this in many steel-Needles, and put them all into the Water, I found, that they all
* stood equi-distant, pointing to the North." This indeed would be contrary to our magnetick rules. For this reason we made an experiment with seventy excellent diamonds, in the presence of many witnesses, on a large number of spikes and wires, with the most careful precautions, floating (thrust, of course, through their corks) on the surface of water; never, however, could we observe this. He was deceived by the verticity acquired from the earth (as stated above) in the spike or wire of iron itself, and the iron itself turned aside to its own definite pole; and he, being ignorant of this, thought it was done by the diamond. But let the investigators of natural

phenomena take heed that they are not the more deceived by their own badly observed experiments, and disturb the commonwealth of letters with their errors and stupidities. Diamond is sometimes designated by the name of *Sideritis*, not because it is made of iron or because it draws iron, but on account of its lustre, resembling flashing steel; with such a lustre do the choicest pieces of diamond shine; hence by very many writers many qualities are imputed to diamond which really belong to siderite loadstone.

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CHAP. XIIII.

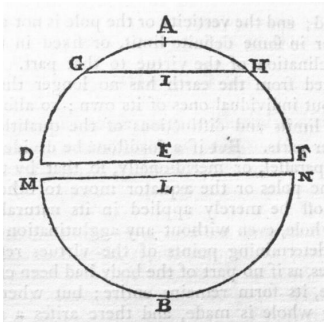
The Placing of a Loadstone above or below a magnetick body suspended in æquilibrium changes neither the power *nor the verticity of the magnetick body.*

Quietly to pass this over would be improper, because a recent error arising from a defective observation of Baptista Porta must be overthrown; on which he (by an unfortunate repetition) even writes three chapters, namely, the 18th, the 31st, and the 42nd. For if a loadstone or a piece of magnetick iron, hanging in æquilibrium or floating on water, is attracted and disposed toward certain definite points, when you bring above it a piece of iron or another loadstone, it will not, if you afterward put the same[215] below it, turn round to the contrary parts; but the same ends of the iron or the loadstone will always be directed toward the same ends of the stone, even if the loadstone or the iron is suspended in any way in æquilibrium or is poised on a needle, so that it can turn round freely. He was deceived by the irregular shape of some stone, or because he did not arrange the experiment suitably. Wherefore he is led astray by a vain opinion, and thinks he may infer that, just as a stone has an arctic and antarctic pole, so also it has a western and an eastern, and an upper and a lower pole. So from foolish ideas conceived and admitted arise other fallacies.

CHAP. XV.

The Poles, Æquator, Centre in an entire Loadstone *remain and continue steady; by diminution and* separation of some part they vary and *acquire other positions.*

* Suppose A B to be a terrella, whose centre is E, and whose diameter (as also its æquinoctial circle) is D F. If you cut off a portion (through the arctic circle, for example), G H, it is demonstrable that the pole which was at A now has a position at I. But the centre and the æquinoctial recede toward B merely so that they are always in the middle of the mass that is left between the plane of the arctick circle G I H and the antarctick pole B. Therefore the segment of the terrella comprised between the plane of the former æquinoctial (that, of course, which was the æquator before cutting that part away) D E F and the newly acquired æquator M L N will always be equal to the half of that part



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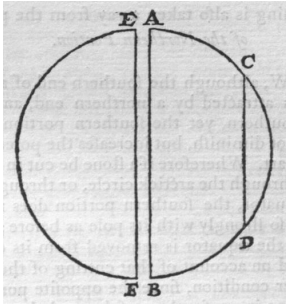
* 

which was cut off, G I H A. But if the portions have been taken away from the side C D, the poles and axis will not be in the line A B, but in E F, and the axis would be changed in the same proportion as the æquator in the former figure. For those positions of forces and virtues, or rather limits of the virtues, which are derived from the whole form, are moved forward by change of quantity and shape; since all these limits arise from the conspiring together of the whole and of all the parts united; {146} and the verticity or the pole is not a virtue innate in one part, or in some definite limit, or fixed in the substance; but it is an inclination of the virtue to that part. And just as a terrella separated from the earth has no longer the earth's poles and æquator, but individual ones of its own; so also if it again be divided, those limits and distinctions of the qualities and virtues pass on to other parts. But if a loadstone be divided in any way, either along a parallel, or meridionally, so that by the change of shape either the poles or the æquator move to other positions, if the part cut off be merely applied in its natural position and joined to the whole, even without any agglutination or cementing together, the determining points of the virtues return again to their former sites, as if no part of the body had been cut off. When a body is entire, its form remains entire; but when the body is lessened, a new whole is made, and there arises a new entirety, determined for every loadstone, however small, even for magnetick gravel, and for the finest sand.

CHAP. XVI.

If the Southern Portion of a Stone be lessened, something is also taken away from the power *of the Northern Portion.*

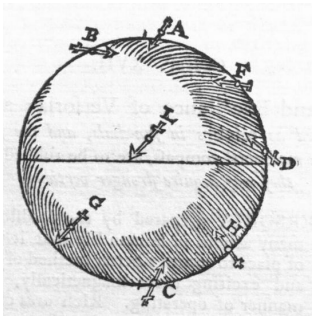
Now although the southern end of a magnetick iron is attracted by a northern end, and repelled by a southern, yet the southern portion of a stone does not diminish, but increases the potency of the boreal part. Wherefore if a stone be cut in two and divided through the arctick circle, or through the tropick of Cancer or the æquator, the southern portion does not attract magnetick substances so strongly with its pole as before; because a new whole arises, and the æquator is removed from its old position and moves forward on account of that cutting of the stone. In the former condition, since the opposite portion of the stone increases the mass beyond the plane of the æquator, it strengthens also the verticity, and the potency, and the motion to unity.

CHAP. XVII. {147}

On the Use and Excellence of Versoria: and how iron *versoria used as pointers in sun-dials, and the fine needles* of the mariners' compass, are to be rubbed, that *they may acquire stronger verticity.*

Versoria prepared by the loadstone subserve so many actions in human life that it will not be out of place to record a better method of touching them and exciting them magnetically, and a suitable manner of operating. Rich ores of iron and such as yield a greater proportion of metal are recognized by means of an iron needle suspended in æquilibrium and magnetically prepared; and magnetick stones, clays, and earths are distinguished, whether crude or prepared. An iron needle (the soul of the mariners' compass), the marvellous director in voyages and finger of God, one might almost say, indicates the course, and has pointed out the whole way around the earth (unknown for so many ages). The Spaniards (as also the English) have frequently circumnavigated (by an immense circuit) the whole globe by aid of the mariners' compass. Those who travel about through the world or who sit at home have sun-dials. A magnetick pointer follows and searches out the veins of ore in mines. By its aid mines are driven in taking cities; catapults and engines of war are aimed by night; it has been of service for the topography of places, for marking off the areas and position of buildings, and for excavating aqueducts for water under ground. On it depend instruments designed to investigate its own dip and variation.

When iron is to be quickened by the stone, let it be clean and bright, disfigured by no rust or dirt, and of the best steel[216]. Let the stone itself be wiped dry, and let it not be damp with any moisture, but let it be filed gently with some smooth piece of iron. But the hitting of the stone with a hammer is of no advantage. By these means let their bare surfaces be joined, and let them be rubbed, so that they may come together more firmly; not so that the material substance of the stone being joined to the iron may cleave to it, but they are rubbed gently together with friction, and (useless parts being rubbed off) they are intimately united; whence a more notable virtue arises in the iron that is excited. A is the best way of touching a versorium when the cusp touches the pole and faces it; B is a moderately good way, when, though facing it, it is a little way distant from the pole; also in like manner C is only moderately good on account of the cusp being turned away from the pole; D, which is farther distant, is hardly so good; F, which is prepared crosswise along a parallel, is bad; of no virtue and entirely irresponsive and feeble is the magnetick index L, which is rubbed along the æquator; oblique and not pointing towards the pole as G, and oblique, not pointing toward but turned away from the pole as H, are bad. These have been placed so that they might indicate the distinct forces of a round stone. But mechanicians very often have a stone tending more to a cone shape, and more powerful on account of that shape since the pole, on which they rub their wires, is at the apex of the projecting part. Sometimes the stone has on the top and above its own pole an artificial acorn or snout made of steel for the sake of its power. Iron needles are rubbed on the top of this; wherefore they turn toward the same pole as if they had been prepared on that part of the stone with the acorn removed. Let the stone be large enough and strong; the needle, even if it be rather long, should be sufficiently thick, not very slender; with a moderate cusp, not too sharp, although the virtue is not in the cusp itself only, but in the whole piece of iron. A strong large stone is not unfit for rubbing all needles on, excepting that sometimes by its strength it occasions some dip and disturbance in the iron in the case of longer needles; so that one which, having been touched before, rested in equilibrium in the plane of the horizon, now when touched and excited dips at one end, as far as the upright pin on which



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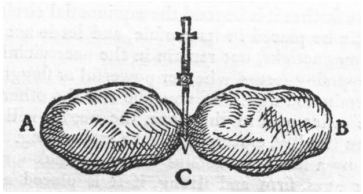
it turns permits it. Wherefore in the case of longer versoria, the end which is going to be the Boreal, before it is rubbed, should be a little lighter, so that it may remain exactly in æquilibrio
* after it is touched. But a needle in this way prepared does its work worse the farther it is beyond {149}
the æquinoctial circle. Let the prepared needle be placed in its capsule, and let it not be touched by any other magneticks, nor remain in the near vicinity of them, lest by their opposing forces, whether powerful or sluggish, it should become uncertain and dull. If you also rub the other end of the needle on the other pole of the stone, the needle will perform its functions more steadily, especially if it be rather long. A piece of iron touched by a loadstone retains the magnetick virtue, excited in it even for ages[217], firm and strong, if it is placed according to nature meridionally and not along a parallel, and is not injured by rust or any external injury from the surrounding medium. Porta wrongly seeks for a proportion between the loadstone and the iron: because, he says, a little piece of iron will not be capable of holding much virtue; for it is consumed by the great force of the loadstone. A piece of iron receives its own virtue fully, even if it be only of the weight of one scruple, whilst the mass of the loadstone is a thousand pounds. It is also useless to make the needle rather flat at the end that is touched, so that it may be better and more perfectly magnetick, and that it may best receive and hold certain magnetick particles; since hardly any part will stick on a sharp point; because he thought that it was by the adhesion of parts of the loadstone (as it were, hairs) that the influence is imparted and conserved, though those particles are merely rubbed off by the rubbing of the iron over the softer stone, and the iron none the less points toward the North and South, if after it is touched it be scoured with sand or emery powder, or with any other material, even if by long rubbing of this kind the external parts of it are lessened and worn away. When a needle is being rubbed, one should always leave off at the end; otherwise, if it is rubbed on the loadstone from the point toward the middle, less verticity is excited in the iron, sometimes none at all, or very little. For where the last contact is, there is the pole and goal of verticity. In order that a stronger verticity may be produced in the iron by
* rubbing on the loadstone, one ought in northern lands to turn the true northern pole of the loadstone toward the highest part of the sky; on this pole that end of the needle is going to be rubbed, which shall afterwards turn toward the north of the earth; whilst it will be an advantage for the other end of the needle to be rubbed on the southern pole of the terrella turned toward the earth, and this being so excited will incline toward the south. In southern regions beyond the æquator the plan is just the contrary. The reason of this dissimilarity is demonstrated, Book II., chap, xxxiv., in which it is shown (by a manifest combination of a terrella and the earth) why the poles of a loadstone, for different reasons, are one stronger than the other. If a needle be touched
* between the mutually accordant poles of two loadstones, equal in power, shape, and mass, no strength is acquired by the needle. A and B are two loadstones {150}



attracting one another, according to nature, at their dissimilar
* ends; C, the point of a needle touched by both at once, is not excited (even if those loadstones be connected according to nature), if they are equal; but if they are not equal, virtue is acquired from the stronger. When a needle is being excited by a loadstone, begin in the middle, and draw the needle toward its end; at the end let the application be continued with a very gentle rubbing around the end for some time; that is to say, for one or two minutes; do not repeat the motion from the middle to the end (as is frequently done) for in this way the verticity is injured. Some delay is desirable, for although the power is imparted instantly, and the iron excited, yet from the vicinity of the loadstone and a suitable delay, a more steady verticity arises, and one that is more firmly durable in the iron. Although an armed stone raises a greater weight of iron than an unarmed one, yet a needle is not more strongly excited by an armed stone than by an unarmed one. Let there be two iron wires of the same length, wrought from the same wire; let one be excited by an armed end, the other by an unarmed end; it is manifest that the same needles have a beginning of motion or a sensible inclination at equal distances from the same armed and unarmed loadstone; this is ascertained by measuring with a longish reed. But objects which are more powerfully excited move more quickly; those which are less powerfully excited, more feebly, and not unless brought rather close; the experiment is made on water with equal corks.

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BOOK FOURTH.

CHAP. I.

ON VARIATION.

Direction has hitherto been spoken of as if in nature there were no variation; for in the preceding natural history we wished to omit and neglect this, inasmuch as in a terrestrial globe, perfect and in every sense complete, there would be none. Since, however, in fact, the earth's magnetick direction, owing to some fault and slip, deviates from its right course and from the meridian, we must extract and demonstrate the obscure and hidden cause of that variance which has troubled and sore racked in vain the minds of many. Those who before us have written on the magnetick movements have made no distinction between direction and variation, but consider the motion of magnetick iron to be uniform and simple. Now true direction is the motion of the magnetick body to the true meridian and its continuance therein with its appropriate ends towards the poles. But it very often happens at sea and on land that the magnetick iron does not point to the true pole, and that not only a versorium and magnetick pieces of iron, and the needle of a compass, or a mariners'
* compass, but also a terrella in its boat, as well as iron ore, iron stones, and magnetick earths, properly prepared, are drawn aside and deviate towards some point of the Horizon very near to the meridian. For they with their poles frequently face termini away from the meridian. This variation (observed by means of instruments or a nautical variation compass) is therefore the arc {152} of the horizon between the common point of intersecion of it with the true meridian, and the terminus of the deflecion on the horizon or projection of the deviating needle. That arc varies and differs with change of locality. To the terminus of the variation is commonly assigned a great circle, called the circle of variation, and also a magnetick meridian passing through the zenith and the point of variation on the horizon. In the northern regions of the earth this variation is either from the north toward the east or from the north toward the west: similarly in the southern regions it is from the south toward the east or toward the west. Wherefore one should observe in
* the northern regions of the earth that end of the versorium or compass which turns toward the North; but in the southern regions the other end looking to the south—which seamen and sciolists for the most part do not understand, for in both regions they observe only the boreal lily of the compass (that which faces North). We have before said that all the motions of the magnet and iron, all its turning, its inclination, and its settlement, proceed from bodies themselves magnetical and from their common mother the earth, which is the source, the propagatrix, and the origin of all these qualities and properties. Accordingly the earth is the cause of this variation and inclination toward a different point of the horizon: but how and by what powers must be more fully investigated. And here we must at the outset reject that common opinion of recent writers concerning magnetick mountains, or any magnetick rock, or any phantasmal pole distant from the pole of the earth, by which the motion of the compass or versorium is controlled. This opinion, previously invented by others, Fracastorio himself adopted and developed; but it is entirely at variance with experience. For in that case in different places at sea and on land the point of variation would change toward the east or west in proportion and geometrical symmetry, and the versorium would always respect the magnetick pole: but experience teaches that there is
* no such definite pole or fixed terminus on the earth to account for the variation. For the arcs of variation are changed variously and erratically, not only on different meridians but on the same meridian; and when, according to this opinion of the moderns, the deviation should be more and more toward the east, then suddenly, with a small change of locality, the deviation is from the north toward the west as in the northern regions near Nova Zembla. Moreover, in the southern regions, and at sea at a great distance from the æquator towards the antarctick pole, there are frequent and great variations, and not only in the northern regions, from the magnetick mountains. But the cogitations of others are still more vain and trifling, such as that of Cortes about a moving influence beyond all the heavens; that of Marsilius Ficinus about a star in the {153} Bear; that of Peter Peregrinus about the pole of the world; that of Cardan, who derives it from the rising of a star in the tail of the Bear[218]; of Bessardus, the Frenchman, from the pole of the Zodiack; that of Livio Sanuto from some magnetick meridian; that of Franciscus Maurolycus from a magnetical island; that of Scaliger from the heavens and mountains; that of Robert Norman, the Englishman, from a point respective. Leaving therefore these opinions, which are at variance with common experience or by no means proved, let us seek the true cause of the variation. The great magnet or terrestrial globe directs iron (as I have said) toward the north and south; and excited iron quickly settles itself toward those termini. Since, however, the globe of the earth is defective and uneven on its surface and marred by its diverse composition, and since it has parts very high and convex (to the height of some miles), and those uniform neither in composition nor body, but opposite and dissimilar: it comes to pass that the whole of that force of the earth diverts magnetical bodies in its periphery toward the stronger and more prominent connected magnetick parts. Hence on the outermost surface of the earth magnetical bodies are slightly perverted from the true meridian. Moreover, since the surface of the globe is divided into high lands and deep seas, into great continental lands, into ocean and vastest seas, and since the force of all magnetical motions is derived from the constant and magnetick terrestrial nature which is more prevalent on the greater continent and not in the aquæous or fluid or unstable part; [219]it follows that in certain parts there would be a magnetick inclination from the true pole east or west away from any meridian (whether passing through seas or islands) toward a great land or continent rising higher, that is, obviously toward a stronger and more elevated magnetick part of the terrestrial globe. For since the diameter of the earth is more than 1,700 German miles, those large lands can rise from the centre of the earth more than four miles above the depth of the ocean bottom, and yet the earth will retain the form of a globe although somewhat uneven at the top. Wherefore a magnetical body is turned aside, so far as the true verticity, when disturbed, admits, and departs from its right (the whole earth moving it) toward a vast prominent mass of land as though toward what is stronger. But the variation does really take place, not so much because of the more prominent and imperfect terrestrial parts and continent lands as because of

the inæquality of the magnetick globe, and because of the real earth, which stands out more under the continent lands than under the depths of the seas. We must see, therefore, how the *apodixis* of this theory can be sustained by more definite observations. Since throughout all the course from the coast of Guinea to Cape Verde, the Canary Isles, and the border of the kingdom of Morocco, and thence along the coasts of Spain, France, England, Belgium, Germany, Denmark, {154}
and Norway, there lie on the right hand and toward the east a continent and extensive connected regions, and on the left extensive seas and a vast ocean lie open far and wide, it is consonant with the theory (as has been carefully observed by many) that magnetical bodies should turn slightly to the East from the true pole toward the stronger and more remarkable elevations of the earth. But it is far otherwise on the eastern shores of northern America; for from Florida by Virginia and Norumbega to Cape Race and away to the north the versorium is turned toward the west. But in the middle spaces, so to speak, as in the more westerly Azores, it looks toward the true pole. That any magnetick body turns itself similarly to the same regions of the earth is not, however, because of that meridian or because of the concordancy of the meridian with any magnetick pole, as the crowd of philosophizers reckon, for it is not so throughout the whole of that meridian. For
* on the same meridian near Brazil something very different occurs, as we will show further on. The variation (cæteris paribus) is always less near the æquator, greater in higher latitudes, with the limitation that it be not very near the pole itself. Hence the variation is greater on the coast of
* Norway and Belgium than on the coast of Morocco or Guinea: greater also near Cape Race than in the harbours of Norumbega or of Virginia. On the coast of Guinea magnetick implements deviate by a third part of one rumbe to the East: in Cape Verde Islands by a half: on the coast of Morocco by two thirds: in England at the mouth of the Thames by a whole rumbe: and at London by nearly eleven degrees and one third. For indeed the moving magnetick virtue is stronger in a higher latitude; and the larger regions extending toward the poles dominate the more, as is easily apparent anywhere on a terrella. For as in the case of true Direction magnetick bodies tend toward the pole (namely, toward the stronger end, the whole earth causing the motion), so also do they incline a little toward the stronger and higher parts by the action of the whole along with the conjoint action of iron bodies.

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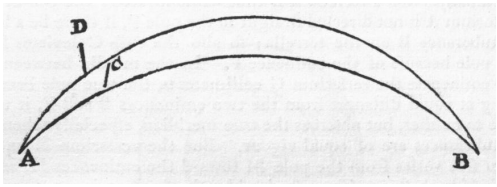
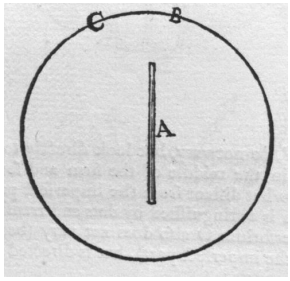
CHAP. II.

That the variation is caused by the inæquality of the *projecting parts of the earth*.

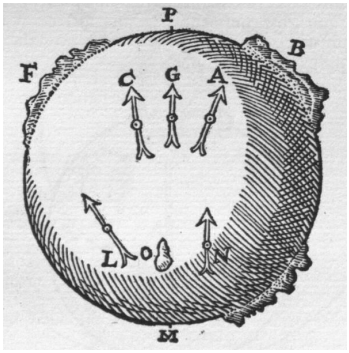
* Demonstration of this may manifestly be made by means of a terrella in the following way: let there be a round loadstone somewhat imperfect in some part, and impaired by decay (such an one we had with a certain part corroded to resemble the Atlantick or great Ocean): place upon it some fine iron wire of the length of two barleycorns, as in the following figure. A B, a Terrella in certain parts somewhat imperfect and of unæqual virtue on the circumference. The versoria E, F, do not vary, but look directly to the pole A; for they are placed in the middle of the firm and sound part of the terrella and somewhat distant from the imperfect part: that part of the surface which is distinguished by dots and transverse lines is the weaker. The versorium O also does not vary (because it is placed in the middle of the imperfect part), but is directed toward the pole, just as near the western {156}
Azores on the earth. The versoria H and L do vary, for they incline toward the sounder parts very near them. As this is manifest in a terrella whose surface is sensibly rather imperfect, so also is it in others whole and perfect, when often one part of the stone has stronger external parts, which nevertheless do not disclose themselves manifestly to the senses. In such a terrella the
* demonstration of the variation and the discovery of the stronger parts is on this wise. Let A be the pole, B the place of the variation, C the stronger regions; then the horizontal versorium at B varies from the pole A toward C: so that both the variation is shown and the stronger places of the loadstone recognized. The stronger surface is also found by a fine iron wire of the length of two barleycorns: for since at the pole of the terrella it rears up perpendicularly, but in other places inclines toward the æquator, if in one and the same parallel circle it should be more erect in one place than in another; where the wire is raised more upright, there the part and surface of the terrella is stronger. Also when the iron wire placed over
* the pole inclines more to one part than to another. Let the experiment be {157}
made by means of a fine iron wire of three digits length placed over the pole A, so that its middle lies over the pole. Then one end is turned away from B toward C, and is not willing to lie quietly toward B; but on a terrella which is perfect[220] all round and even it rests on the pole directed toward any point of the æquator you please. Otherwise, let there be
* two meridians meeting in the poles A B, let iron wires be reared just at the ends D and C of the equal arcs D A and C A; then the wire at D (the stronger region) will be more raised up than that at C, the weaker. And thus the sounder and stronger part of the loadstone is recognized, which



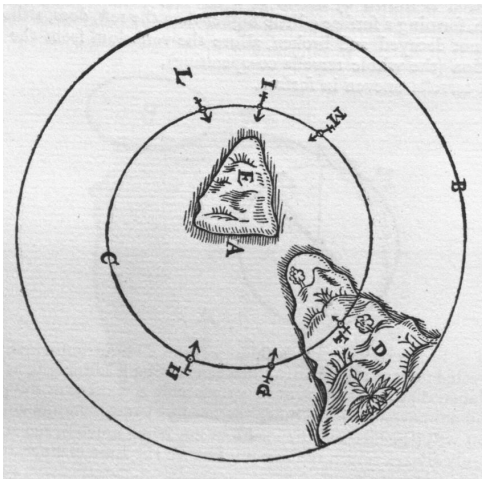
otherwise would not be perceived by the touch. In a terrella which is perfect, and even, and similar in all its parts, there is, at equal distances from the pole, no variation[221]. Variation is shown by means of a terrella, a considerable part of which, forming a surface a little higher than the rest, does, although it be not decayed and broken, allure the versorium
* from the true direction (the whole terrella co-operating).



A terrella uneven in surface.



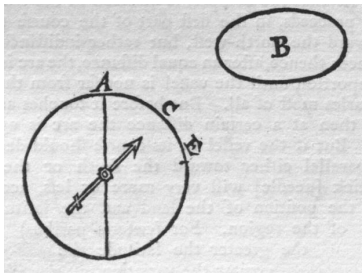
It is shown by a small spike placed over a terrella or by a small versorium; for they are turned by {158}
the terrella toward the mass that stands out and toward the large eminences. In the same way on the earth the verticity is perturbed by great continents, which are mostly elevated above the depths of the seas and make the versorium deviate sometimes from the right tracks (that is, from the true meridians). On a terrella it is thus demonstrated: the end of the versorium A is not directed straight to the pole P, if there be a large protuberance B on the terrella; so also the cusp C deviates from the pole because of the eminence F. In the middle between the two eminences the versorium G collimates to the true pole because, being at equal distances from the two eminences B and F, it turns aside to neither, but observes the true meridian, especially when the protuberances are of equal vigour. But the versorium N on the other side varies from the pole M toward the eminences H, and is not held back, stopped, or restrained by the small eminence O on the terrella (as it were, some island of land in the ocean). L, however, being unimpeded, is directed to the pole M. The variation is demonstrated in another way on a terrella, just as on the earth. Let A be the pole of the earth, B the equator, C the parallel circle of latitude of 30 degrees, D a great eminence spread out toward the pole, E another eminence spread out from the pole toward the æquator. It is manifest that in the middle of D the versorium F does not vary; while G {159}
is very greatly deflected: but H very little, because it is further removed from D. Similarly also the versorium I placed directly toward E does not deviate from the pole: but L and M turn themselves away from the pole A toward the eminence E.



CHAP. III.

The variation in any one place
is constant.

Unless there should be a great dissolution of a continent and a subsidence of the land such as there was of the region Atlantis of which Plato and the ancients tell, the variation will continue perpetually immutable; the arc of the variation remains the same in the same place or region, whether it be at sea or on land, as in times past a magnetick body has declined toward the East or the West. The constancy of the variation and the pointing of the versorium to a definite point on the horizon in individual regions is demonstrated by a small versorium placed over a terrella the surface of which is uneven: for it always deviates from the meridian by an equal arc.



It is also shown by the inclination of a versorium toward a second magnet; although in reality it is by the turning power of the whole, whether in the earth or in a terrella. Place upon a plane a versorium whose cusp is directed toward the north A: place beside it a loadstone, B, at such a distance that the versorium may turn aside toward B to the point C, and not beyond. Then move the needle of the versorium as often as you will (the box and the loadstone not being moved), and it will certainly always return to the point C. In the same manner, if you placed the stone so that {160} it may be truly directed toward E, the cusp always reverts to E, and not to any other point of the compass. Accordingly, from the position of the land and from the distinctive nature of the highest parts of the earth (certain terrene and more magnetick eminences of the regions prevailing), the variation indeed becomes definite in one and the same place, but diverse and unæqual from a change of place, since the true and polar direction originating in the whole terrestrial globe is diverted somewhat toward certain stronger eminences on the broken surface.

CHAP. IIII.

The arc of variation is not changed equally
in proportion to the distance of places.

In the open sea, when a vessel is borne by a favourable wind along the same parallel, if the variation be changed by one degree in the course of one hundred miles, the next hundred miles do not therefore lessen it by another degree; for the magnetick [needle] varies erratically as respects position, form, and vigour of the land, and also because of the distance. As, for example, when a course from the Scilly Isles to Newfoundland has proceeded so far that the compass is directed to the true pole, then, as the vessel proceeds, in the first part of the course the variation increases toward the north-west[222], but rather indistinctly and with small difference: thence, after an equal distance, the arc is increased in a greater proportion until the vessel is not far from the continent: for then it varies most of all. But before it touches actual land or enters port, then at a certain distance the arc is again slightly diminished. But if the vessel in its course should decline greatly from that parallel either toward the south or the north, the magnetick [needle] will vary more or less, according to the position of
* the land and the latitude of the region. For (cæteris paribus) the greater the latitude the greater the variation.

CHAP. V. {161}

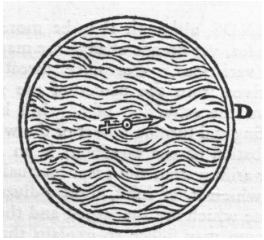
An island in Ocean does not change the variation[223], as
neither do mines of loadstone.

Islands, although they be more magnetick than the sea, yet do not change the magnetick directions or variations. For since direction is a motion derived from the power of the whole earth, not from the attraction of any hill but from the disposing and turning power of the whole; so variation (which is a perturbation of the direction) is an aberration of the real turning power arising from the great inequalities of the earth, in consequence of which it, of itself, slightly diverts movable magneticks toward those which are the largest and the more powerful. The cause now shown may suffice to explain that which some so wonder at about the Island of Elba (and although this is productive of loadstone, yet the versorium (or mariners' compass) makes no special inclination toward it whenever vessels approach it in the Tyrrhenian sea); and the following causes are also to be considered, viz.: that the virtue of smaller magnetick bodies extends scarcely or not at all of itself beyond their own mines: for variation does not occur because of attraction, as they would have it who have imagined magnetick poles. Besides, magnetick mines are only agnate to the true earth, not innate: hence the whole globe does not regard them, and magneticks are not borne to them, as is demonstrated by the diagram of eminences.

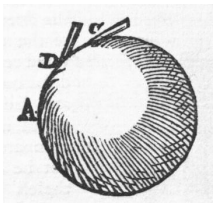
CHAP. VI.

That variation and direction arise from the disponent *power of the earth, and from the natural magnetick tendency* to rotation, not from attraction, or from coition, *or from other occult cause.*

Owing to the loadstone being supposed (amongst the crowd of philosophizers) to seize and drag, as it were, magnetick bodies; and since, in truth, sciolists have remarked no other forces than those so oft besung of attractive ones, they therefore deem every motion toward the north and south to be caused by some alluring and inviting quality. But the Englishman, Robert Norman, first strove to show that it is not caused by {162} attraction: wherefore, as if tending toward hidden principles, he imagined a *point respective*[224], toward which the iron touched by a loadstone would ever turn, not a *point attractive*; but in this he erred greatly, although he effaced the former error about attraction. He, however, demonstrates his opinion in this way:



Let there be a round vessel filled with water: in the middle of the surface of the water place a slender iron wire on a perfectly round cork, so that it may just float in æquilibrium on the water; let the wire be previously touched by a magnet, so that it may more readily show the point of variation, the point D as it were: and let it remain on the surface for some time. It is demonstrable that the wire together with the cork is not moved to the side D of the vessel: which it would do if an attraction came to the iron wire by D: and the cork would be moved out of its place. This assertion of the Englishman, Robert Norman, is plausible and appears to do away with attraction because the iron remains on the water not moving about, as well in a direction toward the pole itself (if the direction be true) as in a variation or altered direction; and it is moved about its own centre without any transference to the edge of the vessel. But direction does not arise from attraction, but from the disposing and turning power which exists in the whole earth, not in the pole or in some other attracting part of the stone, or in any mass rising above the periphery of the true circle so that a variation should occur because of the attraction of that mass. Moreover, it is the directing power of the loadstone and iron and its natural power of turning around the centre which cause the motion of direction, and of conformation, in which is included also the motion of the dip. And the terrestrial pole does not attract as if the terrene force were implanted only in the pole, for the magnetick force exists in the whole, although it predominates and excels at the pole. Wherefore that the cork should rest quiescent in the middle and that the iron excited by a loadstone should not be moved toward the side of the vessel are agreeable to and in conformity with the magnetick nature, as is demonstrated {163}

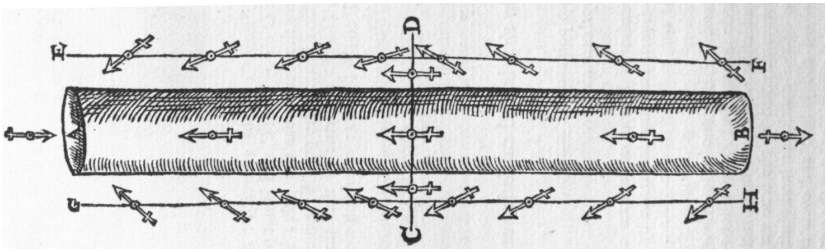


* by a terrella: for an iron spike placed on the stone at C clings on at C, and is not pulled further away by the pole A, or by the parts near the pole: hence it persists at D, and takes a direction toward the pole A; nevertheless it clings on at D and dips also at D in virtue of that turning power by which it conforms itself to the terrella: of which we will say more in the part *On Declination*.

CHAP. VII.

Why the variation from that lateral cause is not *greater than has hitherto been observed, having been* rarely seen to reach two points of the mariners' *compass, except near the pole.*

The earth, by reason of lateral eminences of the stronger globe, diverts iron and loadstone by some degrees from the true pole, or true meridian. As, for example, with us English at London it varies eleven degrees and ⅓: in some other places the variation is a little greater, but in no other region is the end of the iron ever moved aside very much more from the meridian. For as the iron is always directed by the true verticity of the earth, so the polar nature of the continent land (just as of the whole terrene globe) acts toward the poles: and even if that mass divert magnetick bodies from the meridian, yet the verticity of those lands (as also of the whole earth) controls and disposes them so that they do not turn toward the East by any greater arc. But it is not easy to determine by any general method how great the arc of variation is in all places, and how many degrees and minutes it subtends on the horizon, since it becomes greater or less from diverse causes. For {164} both the strength of true verticity of the place and of the elevated regions, as well as their distances from the given place and from the poles of the world, must be considered and compared; which indeed cannot be done exactly: nevertheless by our method the variation becomes so known that no grave error will perturb the course at sea. If the positions of the lands were uniform and straight along meridians, and not defective and rugged, the variations near lands would be simple; such as appear in the following figure.



This is demonstrated by a long loadstone the poles of which are in the ends A B; let C D be the middle line and the æquinoctial, and let G H and E F (the lines) be for meridians on which versoria are disposed, the variations of which are greater at a greater distance from the æquator. But the inequalities of the maritime parts of the habitable earth, the enormous promontories, the very wide gulfs, the mountainous and more elevated regions, render the variations more unequal, or sudden, or more obscure; and, moreover, less certain and more inconstant in the higher latitude.

CHAP. VIII.

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On the construction of the common mariners' compass[225], and on the diversity of the compasses *of different nations*.

In a round[226] hollow wooden bowl, all the upper part of which is closed with glass, a versorium is placed upon a rather long pin which is fixed in the middle. The covering prevents the wind, and the motion of air from any external cause. Through the glass everything within can be discerned. The versorium is circular, consisting of some light material (as card), to the under part of which the magnetick pieces of iron are attached. On the upper part 32 spaces (which are commonly called *points*) are assigned to the same number of mathematical intervals in the horizon or winds which are distinguished by certain marks and by a lily indicating the north. The bowl is suspended in the plane of the horizon in æquilibrium in a brass ring which also is itself suspended transversely in another ring within a box sufficiently wide with a leaden weight attached; hence it conforms to the plane of the horizon even though the ship be tossed to and fro by the waves. The iron works are either a pair with their ends united, or else a single one of a nearly oval shape with projecting ends, which does its work more certainly and more quickly. This is to be fitted to the cardboard circle so that the centre of the circle may be in the middle of the magnetick iron. But inasmuch as variation arises horizontally from the point of the meridian which cuts the horizon at right angles, therefore on account of the variation the makers in different regions and cities mark out the mariners' compass in different ways, and also attach in different ways the magnetick needles to the cardboard circle on which are placed the 32 divisions or points. Hence there are commonly in Europe 4 different constructions and forms. First that of the States on the Mediterranean Sea, Sicily, Genoa, and the Republick of Venice. In all these the needles are attached under the rose or lily on the cardboard versorium, so that (where there is no variation) they are directed to the true north and south points. Wherefore the north part marked with the lily always shows exactly the point of variation when the apex itself of the lily on the movable circle, together with the ends of the magnetick wires attached below, rests at the point of variation. Yet another is that of Dantzig, and throughout the Baltic Sea, and the Belgian provinces; in which the iron works fixed {166} below the circle diverge from the lily ¼ of a rumbe to the east. For navigation to Russia the divergency is ⅔. But the compasses which are made at Seville, Lisbon, Rochelle, Bordeaux, Rouen, and throughout all England have an interval of ½ a rumbe. From those differences most serious errors have arisen in navigation, and in the marine science. For as soon as the bearings of maritime places (such as promontories, havens, islands) have been first found by the aid of the mariners' compass, and the times of sea-tide or high water determined from the position of the moon over this or that point (as they say) of the compass, it must be further inquired in what region or according to the custom of what region that compass was made by which the bearings of those places and the times of the sea-tides were first observed and discovered. For one who should use the British compass and should follow the directions of the marine charts of the Mediterranean Sea would necessarily wander very much out of the straight course. So also he that should use the Italian compass in the British, German, or Baltic Sea, together with marine charts that are made use of in those parts, will often stray from the right way. These different constructions have been made on account of the dissimilar variations, so that they might avoid somewhat serious errors in those parts of the world. But Pedro Nuñez seeks the meridian by the mariners' compass, or versorium (which the Spanish call the needle), without taking account of the variation: and he adduces many geometrical demonstrations which (because of his slight use and experience in matters magnetical) rest on utterly vicious foundations. In the same manner Pedro de Medina, since he did not admit variation, has disfigured his *Arte de Navegar* with many errors.

CHAP. IX.

Whether the terrestrial longitude can be found from *the variation*.

 rateful would be this work to seamen, and would bring the greatest advance to Geography. But B. Porta in chap. 38 of book 7 is mocked by a vain hope and fruitless opinion. For when he supposes that the magnetick needle would follow order and proportion in moving along meridians, so that "the neerer it is to the east, the more it will decline from the Meridian line, toward the east; and the neerer it comes to the west, the point of the needle will decline the more to the west" (which is totally untrue), he thinks {167} that he has discovered a true index of longitude. But he is mistaken. Nevertheless, admitting and assuming these things (as though they were perfectly true), he makes a large compass indicating degrees and minutes, by which these proportional changes of the versorium might be observed. But those very principles are false, and ill conceived, and very ill considered; for the versorium does not turn more to the east because a journey is made toward the east: and although the variation in the more westerly parts of Europe and the adjoining ocean is to the east and beyond the Azores is changed a little to the west, yet the variation is, in various ways, always uncertain, both on account of longitude and of latitude, and because of the approach toward extensive tracts of land, and also because of the form of the dominant terrestrial eminences; nor does it, as we have before demonstrated, follow the rule of any particular meridian. It is with the same vanity also that Livio Sanuto so greatly torments himself and his readers. As for the fact that the crowd of philosophizers and sailors suppose that the meridian passing through the Azores marks the limits of variation, so that on the other and opposite side of that meridian a magnetick body necessarily respects the poles exactly, which is also the opinion of Joannes Baptista Benedictus and of many other writers on navigation, it is by no means true. Stevinus (on the authority of Hugo Grotius) in his *Havenfinding Art* distinguishes the variation according to the meridians: "It may be seene in the Table of variations, that in *Coruo* the Magneticall needle pointeth due North: but after that, the more a man shal goe towards the East, so much the more also shall he see the needle varie towards the East [ἀνατολίζειν], till he come one mile to the Eastward from *Plimouth*, where the variation comming to the greatest is 13 degr. 24 min. From hence the Northeasting [Anatolismus] beginneth to decrease, til you come to *Helmshude* (which place is Westward from the North Cape of Finmark) where againe the needle pointeth due North. Now the longitude from *Coruo* to *Helmshude* is 60 degr. Which things being well weighed, it appeareth that the greatest variation [Chalyboclysis] 13 degr. 24 minutes at *Plimmouth* (the longitude whereof is 30 degr.) is in the midst betweene the places where the needle pointeth due North." But although this is in some part true in these places, yet it is by no means true that along the whole of the meridian of the island of Corvo the versorium looks truly to the north; nor on the meridian of Plymouth is the variation in other places 13 deg. 24 min.—nor again in other parts of the meridian of Helmshuda does it point to the true pole. For on the meridian passing through Plymouth in Latitude 60 degrees the North-easterly variation is greater: in Latitude 40 deg. much less; in Latitude 20 deg. very small indeed. On the meridian of Corvo, although there is no variation near the island, yet in {168} Latitude 55 degrees the variation is about ½ a rumbe to the North-west; in Latitude 20 deg. the versorium inclines ¼ of a rumbe toward the East. Consequently the limits of variation are not conveniently determined by means of great circles and meridians, and much less are the ratios of the increment or decrement toward any part of the heavens properly investigated by them. Wherefore the rules of the abatement or augmentation of Northeasting or Northwesting, or of increasing or decreasing the magnetick deviation, can by no means be discovered by such an artifice. The rules which follow later for variation in southern parts of the earth investigated by the same method are altogether vain and absurd. They were put forth by certain Portuguese mariners, but they do not agree with the observations, and the observations themselves are admitted to be bad. But the method of haven-finding in long and distant voyages by carefully observed variation (such as was invented by Stevinus, and mentioned by Grotius) is of great moment, if only proper instruments are in readiness, by which the magnetick deviation can be ascertained with certainty at sea.

CHAP. X.

Why in various places near the pole the variations are much more ample than in a *lower latitude*.

 ariations are often slight, and generally null, when the versorium is at or near the earth's æquator. In a higher Latitude of 60, 70 or 80 deg. there are not seldom very wide variations. The cause of this is to be sought partly from the nature of the earth and partly from the disposition of the versorium. The earth turns magnetick bodies and at the æquator directs them strongly toward the pole: [227]at the poles there is no direction, but only a strong coition through the congruent poles. Direction is therefore weaker near the poles, because by reason of its own natural tendency to turn, the versorium dips very

much, and is not strongly directed. But since the force of those elevated lands is more vigorous, for the virtue flows from the whole globe, and since also the causes of variation are nearer, therefore the versorium deflects the more from its true direction toward those eminences. It must also be known that the direction of the versorium on its pin along the plane of the Horizon is much stronger at the æquator than anywhere else by reason of the disposition of the versorium; {169} and this direction falls off with an increase of latitude. For on the æquator the versorium is, following its natural property, directed along the plane of the horizon; but in other places it is, contrary to its natural property, compelled into æquilibrium, and remains there, compelled by some external force: because it would, according to its natural property, dip below the horizon in proportion to the latitude, as we shall demonstrate in the book *On Declination*. Hence the direction falls off and at the pole is itself nothing: and for that reason a feebler direction is easily vanquished by the stronger causes of variation, and near the pole the versorium deflects the more from the meridian. It is demonstrated by means of a terrella: if an iron wire of two digits length be placed on its æquator, it will be strongly and rapidly directed toward the poles along the meridian, but more weakly so in the mid-intervals; while near the poles one may discern a precipitate variation.

CHAP. XI.

Cardan's error when he seeks the distance of the *centre of the earth from the centre of the cosmos by the* motion of the stone of Hercules; in his *book 5, On Proportions*.

One may very easily fall into mistakes and errors when one is searching into the hidden causes of things, in the absence of real experiments, and this is easily apparent from the crass error of Cardan; who deems himself to have discovered the distances of the centres of the cosmos and of the earth through a variation of the magnetick iron of 9 degrees. For he reckoned that everywhere on the earth the point of variation on the Horizon is always distant nine degrees from the true north, toward the east: and from thence he forms, by a most foolish error, his demonstrative ratio of the separate centres.

CHAP. XII.

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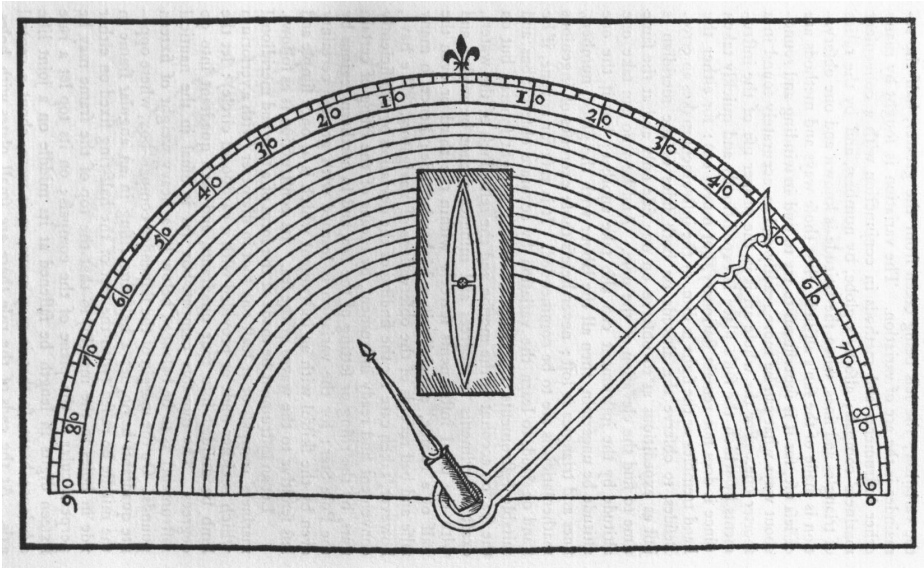
On the finding of the amount of variation: how great *is the arc of the Horizon from its arctick or antarctick* intersection of the meridian, to the point *respective of the magnetick needle*.

Virtually the true meridian is the chief foundation of the whole matter: when that is accurately known, it will be easy by a mariners' compass (if its construction and the mode of attachment of the magnetick iron works are known) or by some other larger horizontal versorium to exhibit the arc of variation on the Horizon. By means of a sufficiently large nautical variation compass (two equal altitudes of the sun being observed before and after midday), the variation becomes known from the shadow; the altitude of the sun is observed either by a staff or by a rather large quadrant.

On land the variation is found in another way which is easier, and because of the larger size of the instrument, more accurate. Let a thick squared board be made of some suitable wood, the surface of which is two feet in length and sixteen inches in width: describe upon it some semicircles as in the following figure, only more in number. In the centre let a brass style be reared perpendicularly: let there be also a movable pointer reaching from the centre to the outmost semicircle, and a magnetick versorium in a cavity covered over with glass: then let the board be exactly adjusted to the level of the Horizon by the plane instrument with its perpendicular; and turn the lily of the instrument toward the north, so that the versorium may rest truly over the middle line of the cavity, which looks toward the point of variation on on the Horizon. Then at some convenient hour in the morning (eight or nine for instance) observe the apex of the shadow thrown by the style when it reaches the nearest semicircle and mark the place of the apex of this shadow with chalk or ink: then bring round the movable index to that mark, and observe the degree on the Horizon numbered from the lily, which the index shows. In the afternoon see when the end of the shadow shall again reach the periphery of the same semicircle, and, bringing the index to the apex of the shadow, seek for the degree on the other side of the lily. From the difference of the degrees becomes known the variation; the less being {172} taken from the greater, half the remainder is the arc of variation. The variation is sought by many other instruments and methods in conjunction with a convenient mariners' compass; also by a globe, by numbers, and by the ratios of triangles and sines, when the latitude is known and one observation is made of the sun's altitude: but those ways and methods are of less use, for it is superfluous to try to find in winding and roundabout ways what can be more readily and as

accurately found in a shorter one. For the whole art is in the proper use of the instruments by which the sun's place is expeditiously and quickly taken (since it does not remain stationary, but moves on): for either the hand trembles or the sight is dim, or the instrument makes an error. Besides, to observe the altitude on both sides of the meridian is just as expeditious as to observe on one side only and at the same time to find the elevation of the pole. And he who can take one altitude by the instrument can also take another; but if the one altitude be uncertain, then all the labour with the globe, numbers, sines and triangles is lost; nevertheless those exercises of ingenious mathematicians are to be commended. It is easy for anyone, if he stand on land, to learn the variation by accurate observations and suitable instruments, especially in a nearly upright sphere; but on the sea, on account of the motion and the restlessness of the waters, exact experiments in degrees and minutes cannot be made: and with the usual instruments scarcely within the third or even the halt of a rumbe, especially in a higher latitude; hence so many false and bad records of the observations of navigators. We have, however, taken care for the finding of the deviation by a sufficiently convenient and ready instrument, by means of the rising of certain stars, by the rising or setting of the sun, and in northern regions by the Pole Star: for the variation is learned with greater certainty even by the skilful with an instrument which is at once simple and less sensitive to the waves of the sea. Its construction is as follows.



[228]Let an instrument be made of the form of a true and meridional mariners' compass of at least one foot in diameter (with a versorium which is either nude or provided with a cardboard circle): let the limb be divided into four quadrants, and each quadrant into 90 degrees. The movable compass-box (as is usual in the nautical instrument) is to be balanced below by a heavy weight of sixteen pounds. On the margin of the suspended compass-box, where opposite quadrants begin, let a half-ring rising in an angular frame in the middle be raised (with the feet of the half-ring fixed on either side in holes in the margin) so that the top of the frame may be perpendicular to the plane of the compass; on its top let a rule sixteen digits in length be fastened at its middle on a joint like a balance beam, so that it may move, as it were, about a central axis. At the ends of the rule there are small plates with holes, through which we can observe the sun or stars. The variation is best observed and expeditiously by this instrument at the equinoxes by the rising or setting sun. But even when the sun is in other parts of the zodiack, the deviation becomes known when we have the altitude of the pole: that being known, one can learn the amplitude on the Horizon and the distance from the true east both of the sun and of the following fixed stars by means of a globe, or tables, or an instrument. Then the variation readily becomes known by counting from the true east the degrees and minutes of the amplitude at rising. Observe the preceding star of the three in the Belt of Orion as soon as it appears on the horizon; direct the instrument toward it and observe the versorium, for since the star has its rising in the true east about one degree toward the south, it can be seen how much the versorium is distant from the meridian, account being taken of that one degree. You will also be able to observe the arctick pole star when it is on the meridian, or at its greatest distance from the meridian of about three degrees (the pole star is distant 2 deg. 55 min. from the pole, according to the observations of Tycho Brahe), and by the instrument you will learn the variation (if the star be not on the meridian) by adding or subtracting, *secundum artem*, the proper reduction [*prostaphæresis*][229] of the star's distance from the meridian. You will find when the pole star is on the meridian by knowing the sun's place and the hour of the night: for this a practised observer will easily

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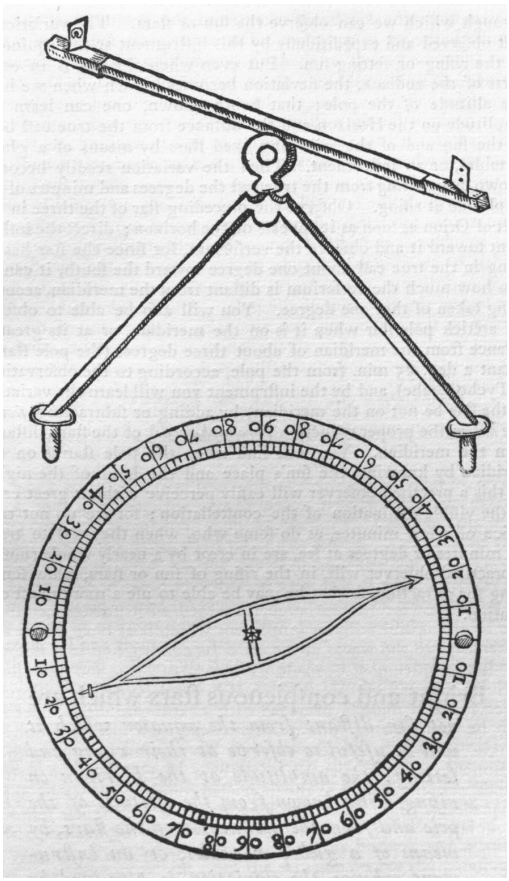

perceive without great error by the visible inclination
of the constellation: for we do not take notice of a few minutes, as do some who, when they toil to track the minutes of degrees at sea, are in error by a nearly whole rumbe. A practised observer will, in the rising of sun or stars, allow something for refraction, so that he may be able to use a more exact calculation.

Bright and conspicuous stars[230] which are *not far distant from the equator which it will be useful to observe at their rising and setting: the amplitude at the Horizon on rising being known from the altitude of the pole and from the declination of the stars, by means of a globe, or tables, or an instrument whence the variation is perceived by technical calculation.*

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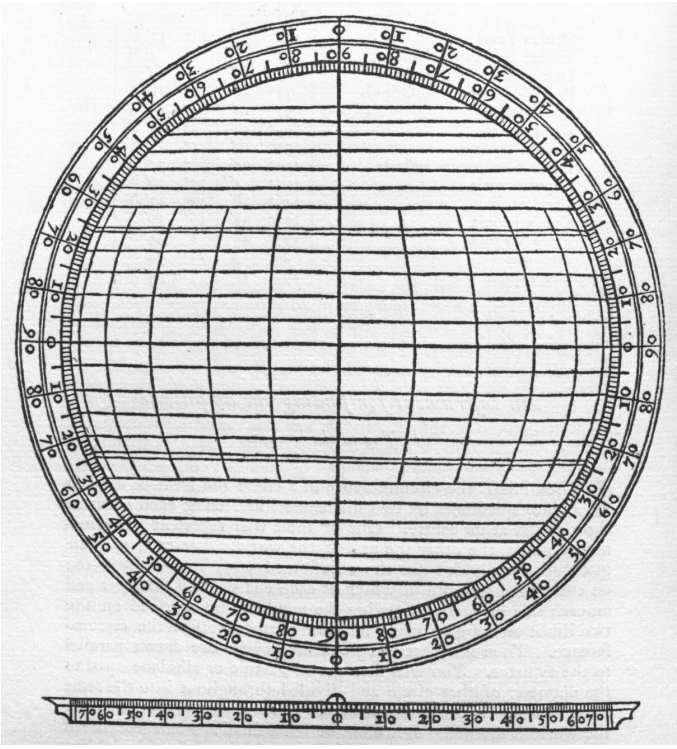
	Right Ascension	*Declination*
Oculus Tauri	62° 55'	15° 53' N
Sinister humerus Orionis	72° 24'	4° 5' N
Dexter humerus Orionis	83° 30'	6° 19' N
Præcedens in cingulo Orionis	77° 46'	1° 16' S
Canis major	97° 10'	15° 55' S
Canis minor	109° 41'	5° 55' N
Lucida Hydræ	137° 10'	5° 3' S
Caput Geminorum australe	110° 21'	28° 30' N
Caput boreale	107° 4'	32° 10' N
Cor Leonis	146° 8'	13° 47' N
Cauda Leonis	171° 38'	16° 30' N
Spica Virginis	195° 44'	8° 34' S
Arcturus	29° 13'	21° 54' N
Cor Aquilæ	291° 56'	7° 35' N

An instrument for finding the amplitude at rising on the horizon.

Describe the circumference of a circle and let it be divided into quadrants by two diameters intersecting each other at right angles at its centre. One of these will represent the æquinoctial circle, the other the axis of the world. Let each of these quadrants be divided (in the accustomed way) into 90 degrees; on every fifth or tenth of which at each end of each diameter and on each side let marks (showing the numbers) be inscribed on the two limbs or margins made for that purpose outside the circumference. Then from each degree straight lines are drawn parallel to the æquator. You will then prepare a rule or alhidade equal to the diameter of that circle and divided throughout into the same parts into which the diameter of the circle representing the axis of the world is divided. Let there be left a small appendage attached to the middle of the rule, by which the middle of the fiducial line itself of the rule may be connected with the centre of the circle: but to every fifth or tenth part of that rule let numbers be attached proceeding from the centre toward each side. This circle represents the plane of the meridian; its centre the actual point of east or west, *i.e.*, the common intersection of the horizon and æquator; all those lines æquidistant from the æquator denote the parallels of the sun and stars; the fiducial line of the rule or alhidade represents the horizon; and its parts signify the degrees of the horizon, beginning from the point of setting or of rising. {176}



Therefore if the fiducial line of the rule be applied to the given latitude of the place reckoned from either end of that diameter which represents the axis of the world; and if further the given declination of the sun or of some star from the æquator (less than the complement of the latitude of the place) be found on the limb of the instrument; then the intersection of the parallel drawn from that point of the declination with the horizon, or with the fiducial line of the rule or alhidade, will indicate for the given latitude of the place the amplitude at rising of the given star or the sun.

CHAP. XIII.

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The observations of variation by seamen vary, for the *most part, and are uncertain: partly from error and inexperience,* and the imperfections of the instruments; and partly *from the sea being seldom so calm that the shadows or lights can remain quite steady on the instruments.*

After the variation of the compass had first been noticed, some more diligent navigators took pains to investigate in various ways the difference of aspect of the mariners' compass. Yet, to the great detriment of the nautical art, this has not been done so exactly as it ought to have been. For either being somewhat ignorant they have not understood any accurate method or they have used bad and absurd instruments, or else they merely follow some conjecture arising from an ill-formed opinion as to some prime meridian or magnetick pole; whilst others again transcribe from others, and parade these observations as their own; and they who, very unskilful themselves, first of all committed their observations to writing are, as by the prerogative of time, held in esteem by others, and their posterity does not think it safe to differ from them. Hence in long navigations, especially to the East Indies, the records by the Portuguese of the deviating compass are seen to be unskilful: for whoever reads their writings will easily understand that they are in error in very many things, and do not rightly understand the construction of the Portuguese compass (the lily of which diverges by half a rumbe from the needles toward the west), nor its use in taking the variation. Hence, while they show the variation of the compass in different places, it is uncertain whether they measure the deviation by a true meridional compass or by some other whose needles are displaced from the lily. The Portuguese (as is patent in their writings) make use of the Portuguese compass, whose magnetick needles are fixed aside from the lily by half of one rumbe toward the east. Moreover on the sea the observation of the variation is a matter of great difficulty, on account of the motion of the ship and the uncertainty of the deviation, even with the more skilful observers, if they use the best made instruments hitherto known and used. Hence there arise different opinions concerning the magnetick deviation: as, for instance, near the Island of St. Helena the Portuguese Rodriguez de Lagos measures half a rumbe. The Dutch in {178} their nautical log fix it at a whole rumbe. Kendall, the expert Englishman, with a true meridional compass admits only a sixth part of a rumbe. A little to the East of Cape Agullias Diego Alfonso makes no variation, and shows by an Astrolabe that the compass remains in the true meridian.

Rodriguez shows that the compass at Cape Agulhas has no variation if it is of Portuguese construction, in which the needles are inclined half a rumbe to the East. And there is the same confusion, negligence, and vanity in very many other instances.

CHAP. XIIII.

On the variation under the æquinoctial line, *and near it.*

In the North the magnetick needle varies because of the Boreal eminences of the continent; in the South because of the Austral; at the æquator, if the regions on both sides were equal, there would be no variation. But because this rarely happens some variation is often observed under the æquator; and even at some distance from the æquator of three or 4 degrees toward the North, there may be a variation arising from the south, if those very wide and influential southern continents be somewhat near on one side.

CHAP. XV.

The variation of the magnetick needle in the great Æthiopick and American sea, beyond *the æquator.*

Discourse hath already been had of the mode and reason of the variation in the great Atlantick Ocean: but when one has advanced beyond the æquator off the east coast of Brazil the magnetick needle turns aside toward the mainland, namely, with that end of it which points to the south; so that with that end of the versorium it deviates from the true meridian toward the west; which navigators observe at the other end and suppose a variation to occur toward the east. But throughout the whole way from the first promontory on the east of Brazil, by Cape St. Augustine and thence to Cape Frio, and further still {179}
to the mouth of the Strait of Magellan, the variation is always from the south toward the west with that end of the versorium which tends toward the antarctick pole. For it is always with the accordant end that it turns toward a continent. The variation, however, occurs not only on the coast itself, but at some distance from land, such as a space of fifty or sixty German miles or even more. But when at length one has progressed far from land, then the arc begins to diminish: for the magnetick needle turns aside the less toward what is too far off, and is turned aside the less from what is present and at hand, since it enjoys what is present. In the Island of St. Helena (the longitude of which is less than is commonly marked on charts and globes) the versorium varies by one degree or nearly two. The Portuguese and others taught by them, who navigate beyond the Cape of Good Hope to the Indies, set a course toward the Islands of Tristan d'Acunha, in order that they may enjoy more favourable winds; in the former part of their course the change of variation is not great; but after they have approached the islands the variation increases; and close to the islands it is greater than anywhere else in the whole course. For the end of the versorium tending to the south (in which lies the greatest source of the variation) is caught and allured toward the south-west by the great promontory of the southern land. But when they proceed onward toward the Cape of Good Hope the variation diminishes the more they approach it. But on the prime meridian in the latitude of 45 degrees, the versorium tends to the south-east: and one who navigates near the coast from Manicongo to the tropick, and a little beyond, will perceive that the versorium tends from the south to the east, although not much. At the promontory of Agulhas it preserves slightly the variation which it showed near the islands of d'Acunha, which nevertheless is very much diminished because of the greater remoteness from the cause of variation, and consequently there the southern end of the versorium does not yet face exactly to the pole.

CHAP. XVI.

On the variation in Nova Zembla.

Variations in parts near the pole are greater (as has been shown before) and also have sudden changes, as in former years the Dutch explorers observed not badly, even if those observations were not exact—which indeed is pardonable in them; for with the usual instruments it is with difficulty that the truth becomes known in such a high {180}
latitude (of about 80 degrees). Now, however, from the deviation of the compass the reason for there being an open course to the east by the Arctick Ocean appears manifest; for since the versorium has so ample a variation toward the north-west, it is demonstrable that a continent does not extend any great distance in the whole of that course toward the east. Therefore with the greater hope can the sea be attempted and explored toward the east for a

passage to the Moluccas by the north-east than by the north-west.

CHAP. XVII.

Variation in the Pacifick Ocean.

assing the Strait of Magellan the deviation on the shore of Peru is toward the south-east, *i.e.*, from the south toward the east. And a similar deflection would be continued along the whole coast of Peru as far as the æquator. In a higher latitude up to 45 deg. the variation is greater than near the æquator; and the deflection toward the south-east is in nearly the same proportion as was the deviation from the south toward the west on the eastern shore of South America. From the æquator toward the North there is little or no variation until one comes to New Galicia; and thence along the whole shore as far as Quivira the inclination is from the north toward the east.

CHAP. XVIII.

On the variation in the Mediterranean Sea.

icilian and Italian sailors think that in the Sicilian Sea and toward the east up to the meridian of the Peloponnesus (as Franciscus Maurolycus relates) the magnetick needle "græcizes," that is, turns from the pole toward what is called the greek wind or Boreas; that on the shore of the Peloponnesus it looks toward the true pole; but that when they have proceeded further east, then it "mistralizes," because it tends from the pole toward the mistral or north-west wind: which agrees with our rule for the variation. For as the Mediterranean Sea is extended toward the west from that meridian, so on the side toward the {181}
east the Mediterranean Sea lies open as far as Palestine; as toward North and East lie open the whole Archipelago and the neighbouring Black Sea. From the Peloponnesus toward the north pole the meridian passes through the largest and most elevated regions of all Europe; through Achaia, Macedonia, Hungary, Transylvania, Lithuania, Novogardia, Corelia and Biarmia.

CHAP. XIX.

The variation in the interior of large *Continents*.

ost of the great seas have great variations; in some parts, however, they have none, but the true directions are toward the pole. On continents, also, the magnetick needle often deviates from the meridian, as on the edge of the land and near the borders; but it is generally accustomed to deviate by a somewhat small arc. In the middle, however, of great regions there are no variations. Hence in the middle lands of Upper Europe, in the interior of Asia, and in the heart of Africa, of Peru, and in the regions of North or Mexican America, the versorium rests in the meridian.

CHAP. XX.

Variation in the Eastern Ocean.

ariation in the Eastern Ocean throughout the whole voyage to Goa and the Moluccas is observed by the Portuguese; but they err greatly in many things, following, as they do, the first observers who note down variations in certain places with ill-adapted instruments, and by no means accurate observations, or by some conjectures. As, for instance, in Brandöe Island, they make the versorium deviate by 22 degrees to the north-west. For in no region or place in the whole world, of not greater latitude, is there so great a deviation; and, in reality, there the deviation is slight. Also when they make out that at Mosambique the compass deviates by one rumbe to the north-west, it is false; even though they use (as they are accustomed to do) the Portuguese compass: for beyond all doubt on the shore of Mosambique the versorium inclines ¼ rumbe or even more to the south-west. Very wrongly also {182}
beyond the æquator in the course to Goa they make the little compass incline by 1½ rumbe to the west: whereas they should rather have said that in the first part of the course the Portuguese compass inclines by 1 rumbe: but that the true meridional compass inclines by ½ rumbe only. In order that the amount of variation in the Eastern Ocean may be accurately settled in most places by our rules, there is needed a more exact and truer survey of the southern land, which spreads

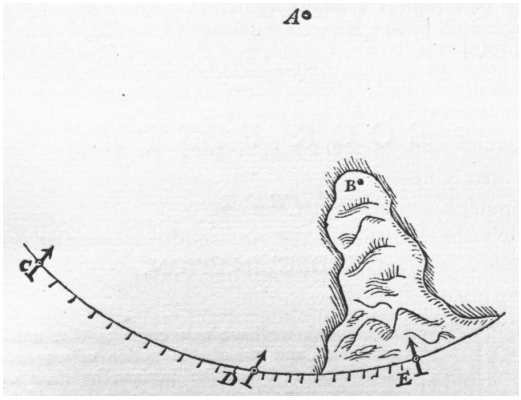
out from the south to the æquinoctial more than is commonly described on maps and globes.

CHAP. XXI.

How the deviation of the versorium is augmented and *diminished by reason of the distance of places.*

In the middle of great and continent lands there is no variation. Nor, generally, in the middle of very great seas. On the margin of those lands and seas the variation is often ample, yet not so great as at a little further distance on the sea. As, for example, near Cape St. Augustine the compass varies; but at 50 miles from land toward the East it varies more; and 80 miles off it varies still more; and yet still more at a distance of 100 miles. But from a distance of 100 miles the diminutions of deviation are slower, when they are navigating toward the mainland, than at a distance of 80 miles, and at a distance of 80 miles than at 50: for the deviations change and are diminished rather more swiftly the more they approach and draw near land than when at a great distance off. As, for instance, navigating toward Newfoundland the change of variation is more rapid (that is, it decreases a degree in a smaller arc of the course on the parallel) when they are not far from land than when they are a hundred miles distant: but when travelling on land toward the interiors of regions the changes are slower in the first parts of the journey than when they come more into the interior.

The ratio of the arcs on a parallel circle, when a versorium is moved toward continents which extend to the pole, corresponds with the degrees of variation. Let A be the pole; B the eminences of the dominant lands; at C there is no variation caused by B, for it is too far away; at D the variation is very great because the versorium is allured or turned by the whole earth toward the eminent land B; and moreover it is not hindered, or restrained or brought back to the pole by the verticity of the earth; but, tending of its own nature to the pole, it is nevertheless deflected from it by reason of the site, or position, and convenient distance of the dominant and high lands. {183}



Now from C toward D the variation increases; the versorium, however, does not deviate so rapidly in the first spaces as near D: for more miles are traversed on the parallel circle C D, near C, in order that the versorium may deviate by one degree from the pole A, than near D. So also in order that the variation may be diminished from D toward E more miles are required near D than near E. Thus the deviations become equal in unequal courses, whether the variation be increasing or decreasing; and yet the variation decreases by lesser intervals than it increases. There intervene, however, many other causes which perturb this proportion.

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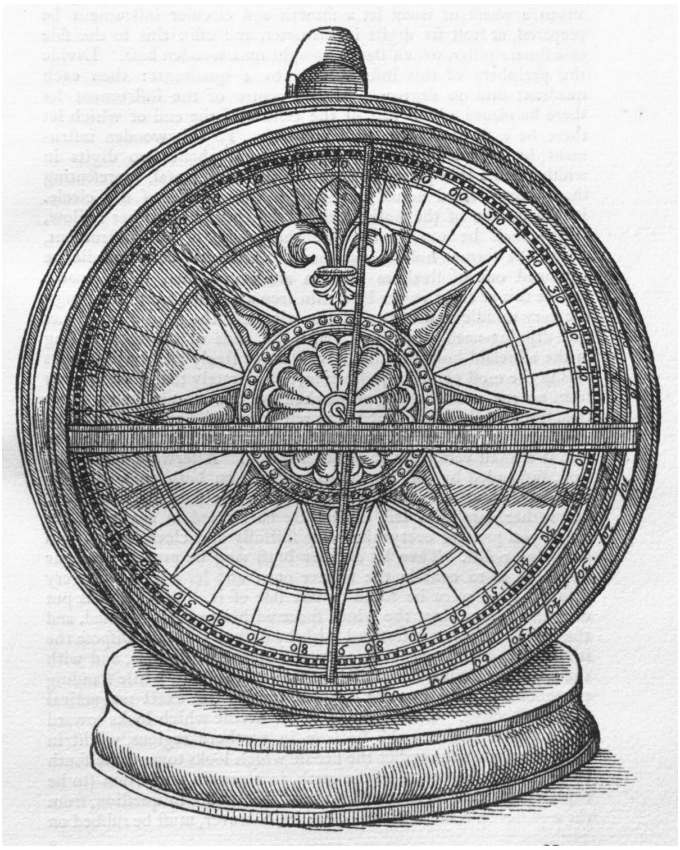
BOOK FIFTH.

CHAP. I.

ON DECLINATION.

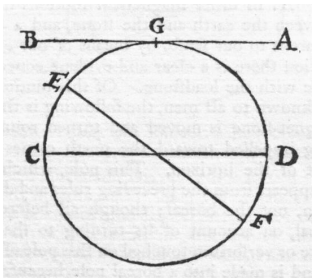
In due course we have now come to that notable experiment, and remarkable motion of magnetick bodies dipping below the horizon by their own rotatory nature; by the knowledge of which is revealed a unity, a concordancy, and a mutual agreement between the terrestrial globe and the loadstone (or the magnetick iron), which is wonderful in itself, and is made manifest by our teaching. This motion we have made known in many striking experiments, and have established its rules; and in the following pages we shall demonstrate the causes of it, in such a way that no sound, logical mind can ever rightly set at nought or disprove our chief magnetick principles. Direction, as also variation, is demonstrated in a horizontal plane, when a balanced magnetick needle comes to rest at some definite point; but declination is seen to be the motion of a needle, starting from that point of the horizon, first balanced on its own axis, then excited by a loadstone, one end or pole of it tending toward the centre of the earth. And we have found that it takes place in proportion to the latitude of each region. But that motion arises in truth, not from any motion from the horizon toward the centre of the earth, but from the turning of the whole magnetick body toward the whole of the earth, as we shall show hereafter. Nor does the iron dip from the horizontal in some oblique sphere, according to the number of degrees of elevation of the pole in the given region, or by an equal arc in the quadrant, as will appear hereafter. {185}

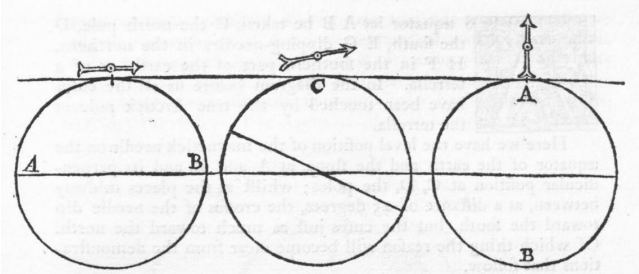
Instrument of the Declination



Now how much it dips at every horizon may be ascertained in the first place by a contrivance, which, however, is not so easily made as is that in dials for measuring time, in which the needle turns to the points of the horizon, or in the mariners' compass. From a plank of wood let a smooth and circular instrument be prepared, at least six digits in diameter, and affix this to the side of a square pillar, which stands upright on a wooden base. Divide the periphery of this instrument into 4 quadrants: then each quadrant into 90 degrees. At the centre of the instrument let there be placed a brass peg, at the centre of the end of which let there be a small hollow, well polished. To this wooden instrument let a brass circle or ring be fixed, about two digits in width, with a thin plate or flat rod of the same metal, representing the horizon, fixed across it, through the middle of the circle. In the middle of the horizontal rod let there be another hollow, which shall be exactly opposite the centre of the instrument, where the former hollow was made. Afterward let a needle be fashioned out of steel, as versoria are accustomed to be made. Divide this at right angles by a thin iron axis (like a cross) through the very middle and centre of the wire and the cross-piece. Let this dipping-needle be hung (with the ends of the cross resting in the aforesaid holes) so that it can move freely and evenly on its axis in the most perfect æquilibrium, so accurately that it turns away from no one point or degree marked on the circumference more than from another, but that it can rest quite easily at any. Let it be fixed upright to the front part of the pillar, whilst at the edge of the base is a small versorium to show direction. Afterward touch the iron, suspended by this ingenious method, on both ends with the opposite ends of a loadstone, according to the scientifick method, but rather carefully, lest the needle be twisted in any way; for unless you prepare everything very skilfully and cleverly, you will secure no result. Then let another brass ring be prepared, a little larger, so as to contain the former one; and let a glass or a very thin plate of mica be fitted to one side of it. When this is put over the former ring, the whole space within remains inclosed, and the versorium is not interfered with by dust or {186}

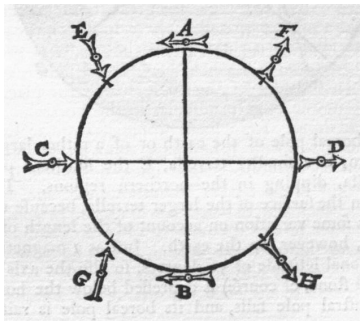
winds. Dispose the instrument, thus completed, perpendicularly on its base, and with the small versorium horizontal, in such a way that, while standing perpendicularly, it may be directed toward the exact magnetical point respective. Then the end of the needle which looks toward the north dips below the horizon in northern regions, whilst in southern regions the end of the needle which looks toward the south tends toward the centre of the earth, in a certain proportion (to be explained afterward) to the latitude of the district in question, from the æquator on either side. The needle, however, must be rubbed on a powerful loadstone; otherwise it does not dip to the {187} true point, or else it goes past it, and does not always rest in it. A larger instrument may also be used, whose diameter may be 10 or 12 digits; but in such an instrument more care is needed to balance the versorium truly. Care must be taken that the needle be of steel; also that it be straight; likewise that both ends of the cross-piece be sharp and fixed at right angles to the needle, and that the cross-piece pass through the centre of the needle. As in other magnetical motions there is an exact agreement between the earth and the stone, and a correspondence manifestly apparent to our senses by means of our experiments; so in this declination there is a clear and evident concordance of the terrestrial globe with the loadstone. Of this motion, so important and so long unknown to all men, the following is the sure and true cause. A magnet-stone is moved and turned round until one of its poles being impelled toward the north comes to rest toward a definite point of the horizon. [231]This pole, which settles toward the north (as appears from the preceding rules and demonstrations), is the southern, not the boreal; though all before us deemed it to be the boreal, on account of its turning to that point of the horizon. A wire or versorium touched on this pole of the stone turns to the south, and is made into a boreal pole, because it was touched by the southern terminal of the stone. So if the cusp of a versorium be excited in a similar manner, it will be directed toward the southern pole of the earth, and will adjust itself also to it; but the cross (the other end) will be southern, and will turn to the north of the earth (the earth itself being the cause of its motion); for so direction is produced from the disposition of the stone or of the excited iron, and from the verticity of the earth. But declination takes place when a magnetick is turned round toward the body of the earth, with its southern end toward the north, at some latitude away from the æquator. For this is certain and constant, that exactly under the cœlestial æquator, or rather over the æquator of the terrestrial globe, there is no declination of a loadstone or of iron; but in whatever way the iron has been excited or rubbed, it settles in the declination instrument precisely along the plane of the horizon, if it were properly balanced before. Now this occurs thus because, when the magnetick body is at an equal distance from either pole, it dips toward neither by its own versatory nature, but remains evenly directed to the level of the horizon, as if it were resting on a pin or floating free and unhindered on water. But when the magnetick substance is at some latitude away from the æquator, or when either pole of the earth is raised (I do not say raised above the visible horizon, as the commonly imagined pole of the revolving universe in the sky, but above the horizon or its centre, or its proper diameter, æquidistant from the plane of the visible horizon, which is the true elevation of the terrestrial pole), then declination is apparent, and the iron {188} inclines toward the body of the earth in its own meridian. Let A B, for example, be the visible horizon of a place; C D the horizontal through the earth, dividing it into equal parts; E F the axis of the earth; G the position of the place. It is manifest that the boreal pole E is elevated above the point C by as much as G is distant from the æquator. Wherefore, since at E the magnetick needle stands perpendicularly in its proper turning (as we have often shown before), so now at G there is a certain tendency to turn in proportion to the latitude (the magnetick dipping below the plane of the horizon), and the magnetick body intersects the horizon at unequal angles, and exhibits a declination below the horizon. For the same reason, if the declinatory needle be placed at G, its southern end, the one namely which is directed toward the North, dips below the plane of the visible horizon A B. And so there is the greatest difference between a right sphere[232] and a polar or parallel sphere, in which the pole is at the very Zenith. For in a right sphere the needle is parallel to the plane of the horizon; but when the cœlestial pole is vertically overhead, or when the pole of the earth is itself the place of the region, then the needle is perpendicular to the horizon. This is shown by a round stone. Let a small dipping-needle, of two digits length (rubbed with a magnet), be hung in the air like a balance, and let the stone be carefully placed under it; and first let the terrella be at right angles, as in a right sphere, and as in the first figure; for so the magnetick needle will remain in equilibrium. But in an oblique position of the terrella, as in an oblique sphere, and in the second figure, the needle dips obliquely at one end toward the near pole, but does not rest on the pole, nor is its dip ruled by the pole, but by the body and mass of the whole; for the dip in higher latitudes passes beyond the pole. But in the third position of the {189} terrella the needle is perpendicular; because the pole of the stone is placed at the top, and the needle tending straight toward the body reaches to the pole. The cross in the preceding figures always turns toward the boreal pole of the terrella, having been touched by the boreal pole of the terrella; the cusp of the needle, having been touched by the southern pole of the stone, turns to the south. Thus one may see on a terrella the level, oblique, and perpendicular positions of a * magnetick needle.





CHAP. II.

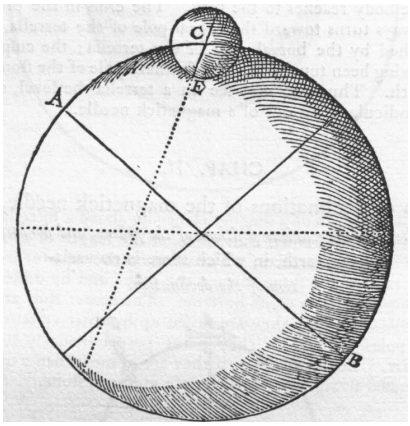
Diagram of declinations of the magnetick needle, when *excited, in the various portions of the sphere, and horizons* of the earth, in which there is no variation *of the declination.*



As æquator let A B be taken, C the north pole, D the south, E G dipping-needles in the northern, H F in the southern part of the earth or of a terrella. In the diagram before us all the cusps have been touched by the true Arctick pole of the terrella. {190}

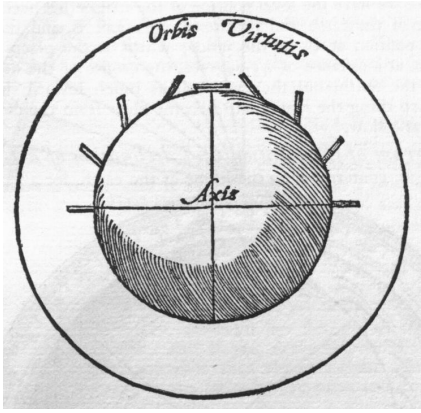
Here we have the level position of the magnetick needle on the æquator of the earth and the stone, at A and B, and its perpendicular position at C, D, the poles; whilst at the places midway between, at a distance of 45 degrees, the crosses of the needle dip toward the south, but the cusps just as much toward the north. Of which thing the reason will become clear from the demonstrations that follow.

* *Diagram of the rotation and declination of a terrella*
conforming to the globe of the earth, for a
latitude of 50 degrees north.



A is the boreal pole of the earth or of a rather large terrella, B the southern, C a smaller terrella, E the southern pole of the smaller terrella, dipping in the northern regions[233]. The centre C is placed on the surface of the larger terrella, because the smaller terrella shows some variation on account of the length of the axis; inappreciable, however, on the earth. Just as a magnetick needle dips in a regional latitude of 50 degrees, so also the axis of a stone (of a spherical stone, of course) is depressed below the horizon, and its natural austral pole falls, and its boreal pole is raised on the south toward the Zenith. In the same way also a circular disc of iron behaves, which has been carefully touched at opposite parts on its circumference; but the magnetical experiments are less clear on account of the feebler forces in round pieces of iron. {191}

Variety in the declinations of iron spikes at various latitudes of a terrella.

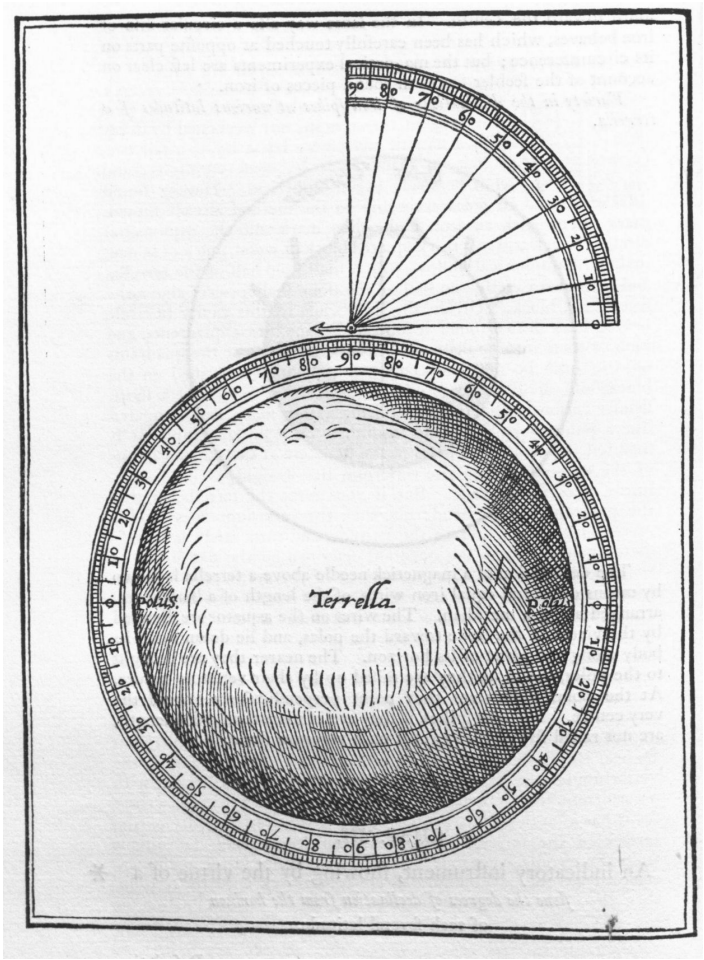


The declination of a magnetick needle above a terrella is shown by means of several equal iron wires, of the length of a barleycorn, arranged along a meridian. The wires on the æquator are directed by the virtue of the stone toward the poles, and lie down upon its body along the plane of its horizon. The nearer they are brought to the poles, the more they are raised up by their versatory nature. At the poles themselves they point perpendicularly toward the very centre. But iron spikes, if they are of more than a due length, are not raised straight up except on a vigorous stone.

CHAP. III.

* **An indicatory instrument, showing by the virtue of a *stone the degrees of declination from the horizon* of each several latitude.**

{192}



Description of the Instrument, and its use.

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Take a terrella of the best strong loadstone, and homogeneous throughout, not weakened by decay or by a flaw in any parts; let it be of a fair size, so that its diameter is six or seven digits; and let it be made exactly spherical. Having found its poles according to the method already shown, mark them with an iron tool; then mark also the æquinoctial circle. Afterwards in a thick squared block of wood, one foot in size, make a hemispherical hollow, which shall hold half of the terrella, and such that exactly one half of the stone shall project above the face of the block. Divide the limb close to this cavity (a circle having been drawn round it for a meridian) into 4 quadrants, and each of these into 90 degrees. Let the terminus of the quadrants on the limb be near the centre of a quadrant described on the block, also divided into 90 degrees. At that centre let a short, slender versorium (its other end being rather sharp and elongated like a pointer) be placed in æquilibrio on a suitable pin. It is manifest that when the poles of the stone are at the starting points of the quadrants, then the versorium lies straight, as if in æquilibrio, over the terrella. But if you move the terrella, so that the pole on the left hand rises, then the versorium rises on the meridian in proportion to the latitude, and turns itself as a magnetick body; and on the quadrant described on the flat surface of the wood, the degree of its turning or of the declination is shown by the versorium. The rim of the cavity represents a meridional circle, to which corresponds some meridian circle of the terrella, since the poles on both sides are within the circumference of the rim itself. These things clearly always happen on the same plan on the earth itself when there is no variation; but when there is variation, either in the direction or in the declination (a disturbance, as it were, in the true turning, on account of causes to be explained later), then there is some difference. Let the quadrant be near the limb, or have its centre on the limb itself, and let the versorium be very short, so as not to touch the terrella, because with a versorium that is longer or more remote, there is some error; for it has a motion truly proportionate to the terrella only on the surface of the terrella. But if the quadrant, being far distant from the terrella, were moved within the orbe of virtue of the terrella toward the pole on some circle concentrick with the terrella, then the versorium would indicate the degrees of declination on the quadrant, in proportion to and symmetrically with that circle, not with the terrella.

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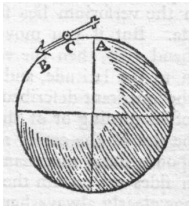
CHAP. IIII.

Concerning the length of a versorium convenient *for declination on a terrella.*

Declination being investigated on the earth itself by means of a declination instrument, we may use either a short or a very long versorium, if only the magnetick virtue of the stone that touches it is able to permeate through the whole of its middle and through all its length. For the greatest length of a versorium has no moment or perceptible proportion to the earth's semi-diameter. On a terrella, however, or in a plane near a meridian of a terrella, a short versorium is desirable, of the length, say, of a barleycorn; for longer ones (because they reach further) dip and turn toward the body of the terrella suddenly and irregularly in the first degrees of declination. For example, as soon as the long versorium is moved forward from the aequator A to C, it catches on the stone with its cusp (as if with a long extended wing), when the cusp reaches to the parts about B, which produce a greater rotation than at C. And the extremities of longer wires also and rods turn irregularly, just as iron wires and balls of iron and other orbicular loadstones are likewise turned about irregularly by a long non-orbicular loadstone. Just so magneticks or iron bodies on the surface of a terrella ought not to have too long an axis, but a very short one; so that they may make a declination on the terrella truly and naturally proportionate to that on the earth. A long versorium also close to a terrella with difficulty stands steady in a horizontal direction on a right sphere, and, beginning to waver, it dips immediately to one side, especially the end that was touched, or (if both were touched) the one which felt the stone last.



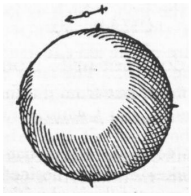
{195}

CHAP. V.

That declination does not arise from the attraction of the loadstone, but from a disposing and *rotating influence.*

In the universe of nature that marvellous provision of its Maker should be noticed, whereby the principal bodies are restrained within certain habitations and fenced in, as it were (nature controlling them). For this reason the stars, though they move and advance, are not thrown into confusion. Magnetical rotations also arise from a disposing influence, whether in greater and dominating quantity, or in a smaller, and compliant quantity, even though it be very small. For the work is not accomplished by attraction, but by an incitation of each substance, by a motion of agreement toward fixed bounds, beyond

which no advance is made. For if the versorium dipped by reason of an attractive force, then a terrella made from a very strong magnetick stone would cause the versorium to turn toward itself more than one made out of an average stone, and a piece of iron touched with a vigorous loadstone would dip more. This, however, never happens. Moreover, an iron snout placed on a meridian in any latitude does not raise a spike more toward the perpendicular than the stone itself, alone and unarmed; although when thus equipped, it plucks up and raises many greater weights[234]. But if a loadstone be sharper toward one pole, toward the other blunter, the sharp end or pole allures a magnetick needle more strongly, the blunt, thick end makes it rotate more
* strongly; but an orbicular stone makes it rotate strongly and truly, in accordance with magnetick rules and its globular form. A long stone, on the other hand, extended from pole to pole, moves a versorium toward it irregularly; for in this case the pole of the versorium always looks down on the pole itself. Similarly also, if the loadstone have been made in the shape of a circle, and its poles are on the circumference, whilst the body of it is plane, not globular, if the plane be brought near a versorium, the versorium does not move with the regular magnetick rotation, as on a terrella; but it turns looking always toward the pole of the loadstone, which has its seat on the circumference of the plane. Moreover, if the stone caused the versorium to rotate by attracting it, then in the first degrees of latitude, it would attract the end of a short versorium toward the body itself of the terrella; yet it does not so attract it that they are brought into contact and unite; but the versorium rotates just so far as nature demands, as is clear from this
* example. For the cusp of a versorium placed in a low latitude does not touch {196}

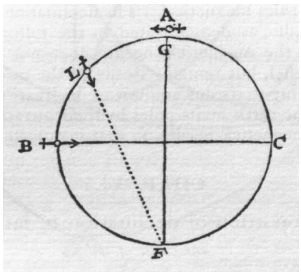


the stone or unite with it, but only inclines toward it. Moreover, when a magnetick body rotates in dipping, the pole of the versorium is not stayed or detained by the pole of the earth or terrella; but it rotates regularly, and does not stop at any point or bound, nor point straight to the pole toward which the centre of the versorium is advancing, unless on the pole itself, and once only between the pole and the æquator; but it dips as it advances, according as the change of position of its centre gives a reason for its inclination in accordance with rules magnetical. The declination of a magnetick needle in water also, as demonstrated in the following pages, is a fixed quantity[235]; the magnetick needle does not descend to the bottom of the vessel, but remains steady in the middle, rotated on its centre according to its due amount of declination. This would not happen, if the earth or its poles by their attraction drew down the end of the magnetick needle, so that it dipped in this way.

CHAP. VI.

On the proportion of declination to latitude[236], and *the cause of it.*

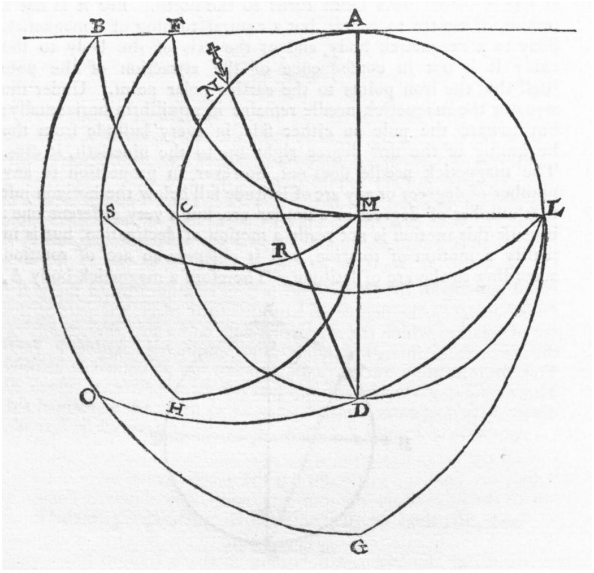
Concerning the making of an instrument for finding declination, the causes and manner of declination, and the different degrees of rotation in different places, the inclination of the stone, and concerning an instrument indicating by the influence of a stone the degree of declination from any horizon we have already spoken. Then we spoke about needles on the meridian of a stone, and their rotation shown for various latitudes by their rise toward the perpendicular. We must now, however, treat more fully of the causes of the degree of that inclination. Whilst a loadstone and a magnetick iron wire are moved along a meridian from the aequator toward the pole, they rotate toward a round loadstone, as also toward the earth with a circular movement. On a right horizon (just as also on the æquinoctial of the stone) the axis of the iron, which is its centre line, is a line parallel to the axis of the earth. {197}
When that axis reaches the pole, which is the centre of the axis, it stands in the same straight line with the axis of the earth. The same end of the iron which at the æquator looks south turns to the north. For it is not a motion of centre to centre, but a natural turning of a magnetick body to a magnetick body, and of the axis of the body to the axis; it is not in consequence of the attraction of the pole itself that the iron points to the earth's polar point. Under the æquator the magnetick needle remains in æquilibrio horizontally; but toward the pole on either side, in every latitude from the beginning of the first degree right up to the ninetieth, it dips. The magnetick needle does not, however, in proportion to any number of degrees or any arc of latitude fall below the horizon just that number of degrees or a similar arc, but a very different one: because this motion is not really a motion of declination, but is in reality a motion of rotation, and it observes an arc of rotation according to the arc of latitude. Therefore a magnetick body A, while it is advancing over the earth itself, or a little earth or terrella, from the æquinoctial G toward the pole B, rotates on its own centre, and halfway on the progress of its centre[237] from the æquator to the pole B it is pointing toward the æquator at F, midway between the two poles. Much more quickly, therefore, must the versorium rotate than its centre advances, in order that by rotating it may face straight toward the point F. Wherefore the motion of this rotation is rapid in the first degrees from the æquator, namely, from A to L; but more tardy in the later degrees from L to B, when facing from the æquator at F to C. But if the declination were equal to the latitude (*i.e.*, always just as many degrees from the horizon, as the centre of the versorium has receded from the æquator), then the magnetick needle would be following some potency and



peculiar virtue of the centre, as if it were a point operating by itself. But it pays regard to the whole, both its mass, and its outer limits; the forces of both uniting, as well of the magnetick * versorium as of the earth. {198}

CHAP. VII.

Explanation of the diagram of the rotation of *a magnetick needle.*



Suppose A C D L to be the body of the earth or of a terrella, its centre M, Æquator A D, Axis C L, A B the Horizon, which changes according to the place. From the point F on a Horizon distant from the æquator A by the length of C M, the semi-diameter of the earth or terrella, an arc is described to H as the limit of the quadrants of declination; for all the quadrants of declination serving the parts from A to C begin from that arc, and terminate at M, the centre of the earth. The semi-diameter of this arc is a chord drawn from the æquator A to the pole C; and a line produced along the horizon from A to B, equal to that chord, gives the beginning of the arc of the limits of arcs of rotation and revolution, which is continued as far as G. For just as a quadrant of a circle about the centre of the earth (whose beginning is on the horizon, at a distance from the æquator equal to the earth's semi-diameter) is the limit of all quadrants of declination drawn from each several horizon to the centre; so a circle about the centre from B, the beginning of the first arc of rotation, to G is the limit of the arcs of rotation. The arcs of rotation and revolution of the magnetick needle are intermediate between the arcs of rotation B L and G L. The centre of the arc is the region itself or place in which the observation is being made; the beginning of the arc is taken from the circle which is the limit of rotations, and it stops at the opposite pole; as, for example, from O to L, in a latitude of 45 degrees. Let any arc of rotation be divided into 90 equal parts from the limit of the arcs of rotation toward the pole; for whatever is the degree of latitude of the place, the part of the arc of rotation which the magnetick pole on or near the terrella or the earth faces in its rotation is to be numbered similarly to this. The straight lines in the following larger diagram show this. The magnetick rotation at the middle point in a latitude of 45 degrees is directed toward the æquator, in which case also that arc is a quadrant of a circle from the limit to the pole; but previous to this all the arcs of rotation are greater than a quadrant, whilst after it they are smaller; in the former the needle rotates more quickly, but in the succeeding positions gradually more slowly. For each several region there is a special arc of rotation, in which the limit to which the needle rotates is according to the number of degrees of latitude of the place in question; so that a straight line drawn from the place to the point on that arc marked with the number of degrees of latitude shows the magnetick direction, and indicates the degree of declination at the intersection of the quadrant of declination which serves the given place. Take away the arc of the quadrant of declination drawn from the centre to the line of direction; that which is left is the arc of declination below the horizon. As, for example, in the rotation of the versorium N, whose line respective proceeds to D, from the quadrant of declination, S M, take away its arc R M; that which is left is the arc of declination: how much, that is, the needle dips in the latitude of 45 degrees. {199}

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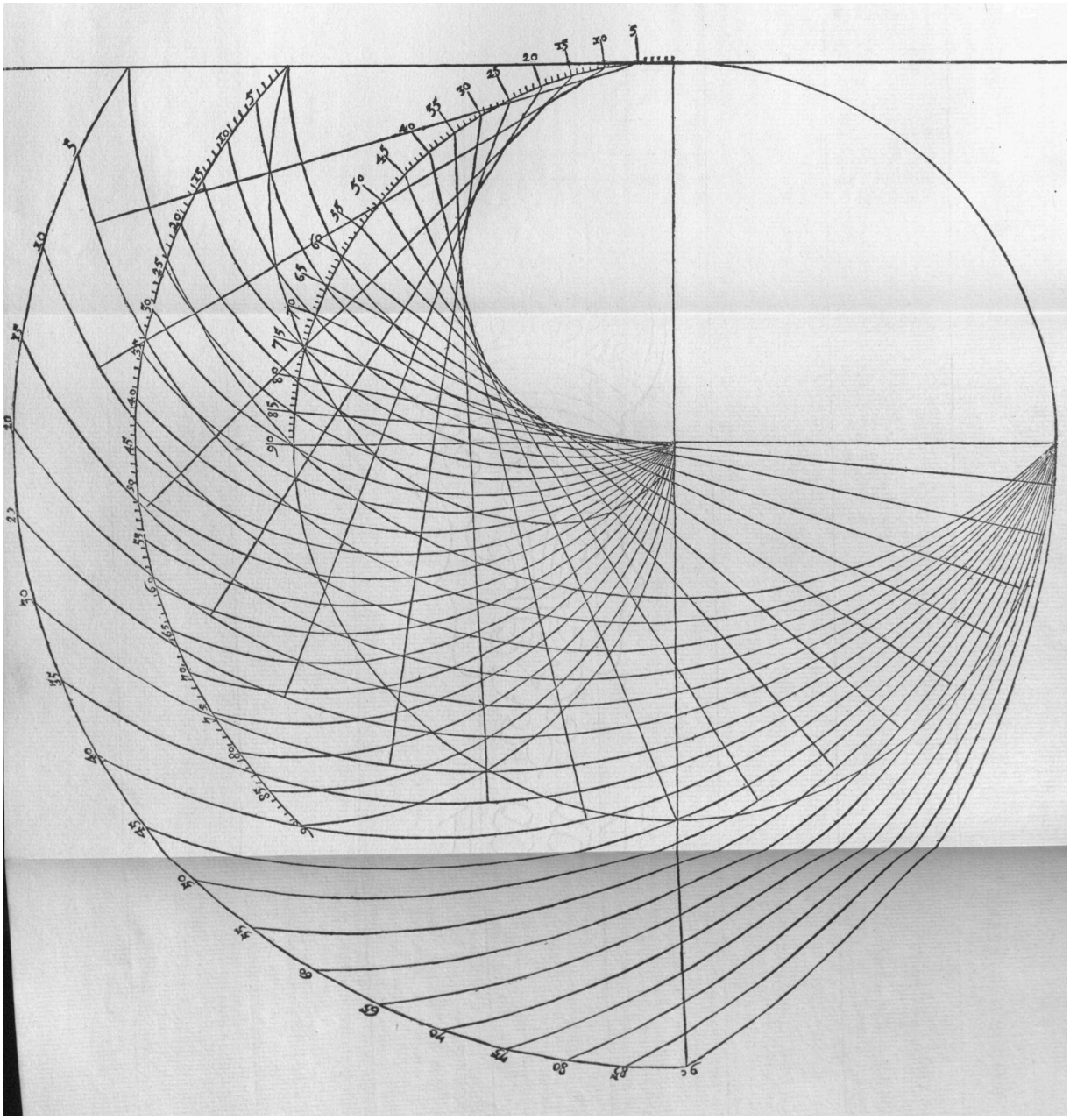
CHAP. VIII.

Diagram of the rotation of a magnetick needle, *indicating magnetical declination in all latitudes, and* from the rotation and declination, the *latitude itself.*

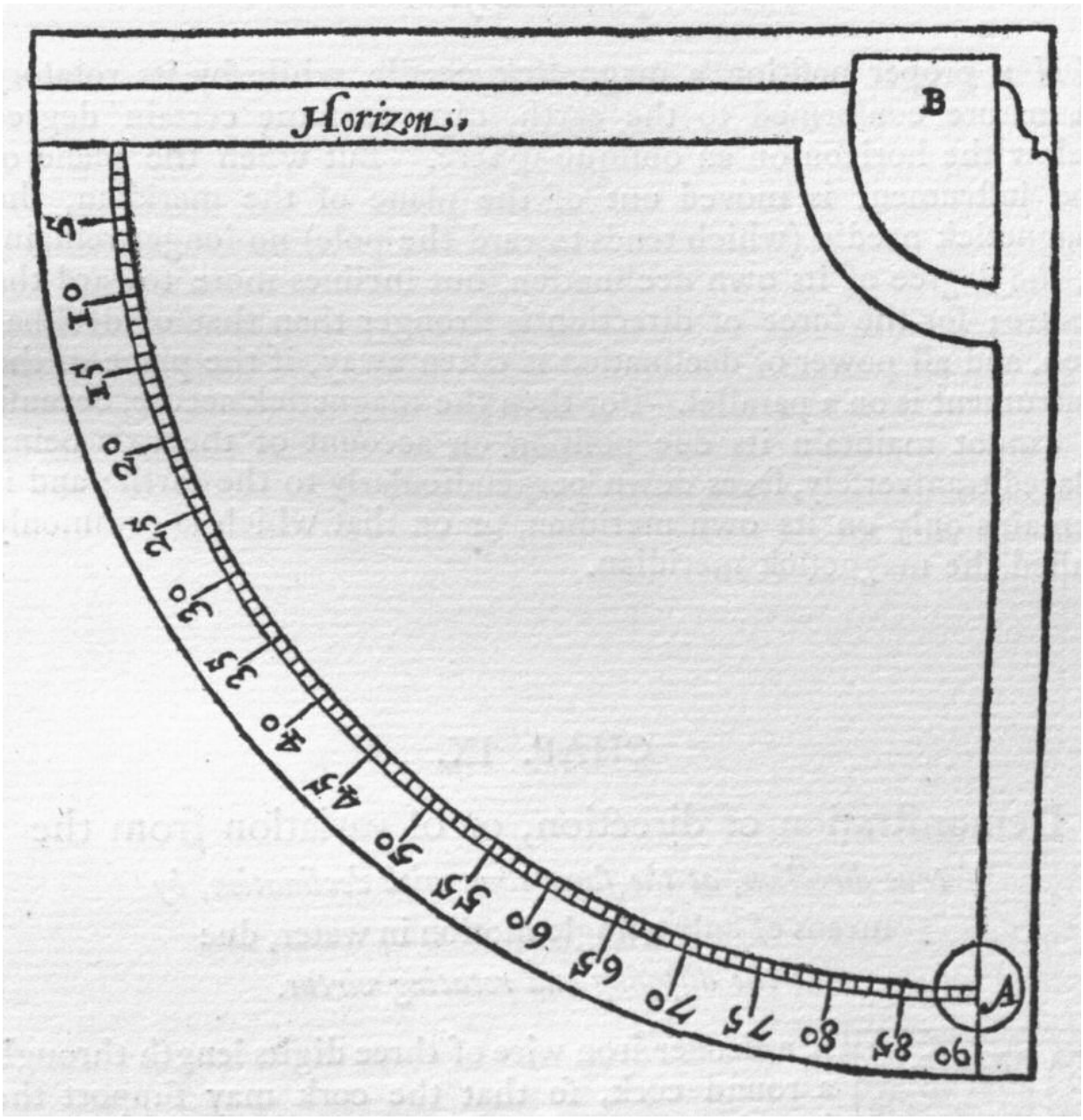
In the more elaborate diagram a circle of rotations and a circle of declinations are adjusted to the body of the earth or terrella, with a first, a last, and a middle arc of rotation and declination. Now from each fifth division of the arc which limits all the arcs of rotation (and which are understood[238] as divided into 90 equal parts) arcs are drawn to the pole, and from every fifth degree of the arc limiting the quadrants of declination, quadrants are drawn to the centre; and at the same time a spiral line is drawn,

indicating (by the help of a movable quadrant) the declination in every latitude. Straight lines showing the direction of the needle are drawn from those degrees which are marked on the meridian of the earth or a terrella to their proper arcs and the corresponding points on those arcs.

To ascertain the elevation of the pole or the latitude of a place anywhere *in the world, by means of the following diagram, turned into a magnetick instrument, without the help of the cœlestial bodies, sun, planets, or fixed stars, in fog and darkness*.



We may see how far from unproductive magnetick philosophy is, how agreeable, how helpful, how divine! Sailors when tossed about on the waves with continuous cloudy weather, and unable by means of the cœlestial luminaries to learn anything about the place or the region in which they are, with a very slight effort and with a small instrument are comforted, and learn the latitude of the place. With a declination instrument the degree of declination of the magnetick needle below the horizon is observed; that degree is noted on the inner arc of the quadrant, and the quadrant is turned round about the centre of the instrument until that degree on the quadrant touches the spiral line; then in the open space B at the centre of the quadrant the latitude of the region on the circumference of the globe is discerned by means of the fiducial line {201}
A B. Let the diagram be fixed on a suitable flat board, and let the centre of the corner A of the quadrant be fastened to the centre of it, so that the quadrant may rotate on that centre. But it must be understood that there is also in certain places a variation in the declination on account of causes already mentioned (though not a large one), which it will be an assistance also to allow for on a likely estimate; and it will be especially helpful to observe this variation in various places, as it seems to present greater difficulty than the variation in direction; but it is easily learnt with a declination instrument, when it dips more or less than the line in the diagram.



To observe magnetick declination at sea.

Set upon our variation instrument a declination instrument; a wooden disc being placed between the round movable compass and the declination instrument: but first remove the versorium, lest the versorium should interfere with the dipping needle. In this way (though the sea be rough) the compass box will remain upright at the level of the horizon. The stand of the declination instrument must be directed by means of the small versorium at its base, which is set to the point respective of the variation, on the great circle of which (commonly called the magnetick meridian), the plane of the upright box is arranged; thus the declinatorium (by its versatory nature) indicates the degree of declination. {202}

In a declination instrument the magnetick needle, which
in a meridional position dips, if turned
along a parallel hangs perpendicularly.

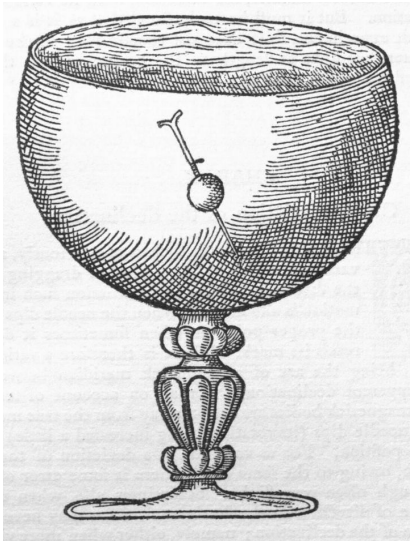
In a proper position a magnetick needle, while by its rotatory nature conformed to the earth, dips to some certain degree below the horizon on an oblique sphere. But when the plane of the instrument is moved out of the plane of the meridian, the magnetick needle (which tends toward the pole) no longer remains at the degree of its own declination, but inclines more toward the centre; for the force of direction is stronger than that of declination, and all power of declination is taken away, if the plane of the instrument is on a parallel. For then the magnetick needle, because it cannot maintain its due position on account of the axis being placed transversely, faces down perpendicularly to the earth; and it remains only on its own meridian, or on that which is commonly called the magnetick meridian.

CHAP. IX.

Demonstration of direction, or of variation from the

true direction, at the same time with declination, by
means of only a single motion in water, due
to the disposing and rotating virtue.

* Fix a slender iron wire of three digits length through a round cork, so that the cork may support the iron in water. Let this water be in a good-sized glass vase or bowl. Pare the round cork little by little with a very sharp knife (so that it may remain round), until it will stay motionless one or two digits below the face of the water; and let the wire be evenly balanced. [239]Rub one end of the wire thus prepared on the boreal end of a loadstone and the other on the southern part of the stone (very skilfully, so that the cork may not be moved ever so little from its place) and again place it in the water; then the wire will dip with a circular motion on its own centre below the plane of the horizon, in proportion to the latitude of the region; and, even while dipping, will also show the point of variation (the true direction being perturbed). Let the loadstone (that with which the iron is rubbed) be a strong one, such as is needed in all experiments on magnetick declination. When the iron, thus put into the water and prepared by means of the loadstone, has settled in the dip, the lower end remains at the point of variation on the arc of a great circle or magnetick meridian passing through the Zenith or vertex, and the point of variation on the horizon, and the lowest point of the heavens, which they call the Nadir. This fact is shown by placing a rather long magnetick versorium on one side a little way from the vase. This is a demonstration of a more absolute conformity of a magnetick body with the earth's body as regards unity; in it is made apparent, in a natural manner, the direction, with its variation, and the declination. But it must be understood that as it is a curious and difficult experiment, so it does not remain long in the middle of the water, but sinks at length to the bottom, when the cork has imbibed too much moisture.



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CHAP. X.

On the variation of the declination.

* Direction has been spoken of previously, and also variation, which is like a kind of dragging aside of the direction. Now in declination such irregular motion is also noticed, when the needle dips beyond the proper point or when sometimes it does not reach its mark. There is therefore a variation of declination, being the arc of a magnetick meridian between the true and apparent declination. For as, on account of terrestrial elevations, magnetick bodies are drawn away from the true meridian, so also the needle dips (its rotation being increased a little) beyond its genuine position. For as variation is a deviation of the direction, so also, owing to the same cause, there is some error of declination, though often very slight. Sometimes, also, when there is no variation of direction in the horizontal, there may nevertheless be variation of the declination; namely, either when more vigorous parts of the earth crop out exactly meridionally, *i.e.* under the very meridian; or when those parts are less powerful than nature in general requires; or when the virtue is too much intensified in one part, or weakened in another, just as one may observe in the vast ocean. And this discrepant nature and varying effect may be easily seen in certain parts of almost any round loadstone. Inæquality of power is recognized in any part of a terrella by trial of the demonstration in chap. 2 of this book. But the effect is clearly demonstrated by the instrument for showing declination in chap. 3 of this book.

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CHAP. XI.

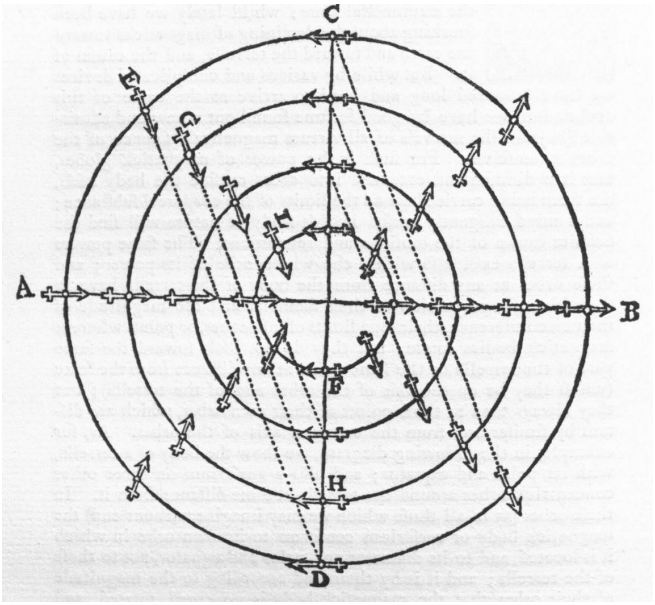
On the essential magnetick activity sphærically
effused.

* Discourse hath often been held concerning the poles of the earth and of the stone, and concerning the æquinoctial zone; whilst lately we have been speaking about the declining of magneticks toward the earth and toward the terrella, and the causes of it. But while by various and complicated devices we have laboured long and hard to arrive at the cause of this declination, we have by good fortune found out a new and admirable (beyond the marvels of all virtues magnetical) science of the orbes themselves. For such is the power of magnetick globes, that it is diffused and extended into orbes outside the body itself, the form being carried beyond the limits of the corporeal substance; and a mind

diligently versed in this study of nature will find the definite causes of the motions and revolutions. The same powers of a terrella exist also within the whole orbe of its power; and these orbes at any distance from the body of the terrella have in themselves, in proportion to their diameter and the magnitude of their circumference, their own limits of influences, or points wherein magnetick bodies rotate; but they do not look toward the same part of the terrella or the same point at any distance from the same (unless they be on the axis of the orbes and of the terrella); but they always tend to those points of their own orbes, which are distant by similar arcs from the common axis of the orbes. As, for example, in the following diagram, we show the body of a terrella, with its poles and æquator; and also a versorium on three other concentrick orbes around the terrella at some distance from it. In these orbes (as in all those which we may imagine without end) the magnetick body or versorium conforms to its own orbe in which it is located, and to its diameter and poles and æquator, not to those of the terrella; and it is by them and according to the magnitude of their orbes that the magnetick body is governed, rotated, and directed, in any arc of that orbe, both while the centre of the magnetick body stands still, and also while it moves along. And yet we do not mean that the magnetick forms and orbes exist in air or water or in any medium that is not magnetical; as if the air or the water were susceptible of them, or were induced by them; for the forms are only effused and really subsist when magnetick substances are there; whence a magnetick body is laid hold of within the forces and limits of the orbes; and within the orbes magneticks dispose magneticks and incite them, as if the orbes of {206} virtue were solid and material loadstones. For the magnetick force does not pass through the whole medium or really exist as in a continuous body; so the orbes are magnetick, and yet not real orbes nor existent by themselves.

Diagram of motions in magnetick orbes.

A B is the axis of the terrella and of the orbes, C D the æquator. On all the orbes, as on the terrella, at the equator the versorium arranges itself along the plane of the horizon; on the axis it everywhere looks perpendicularly toward the centre; in the intermediate spaces E looks toward D; and G looks toward H, not toward F, as the versorium L does on the surface of the terrella. But as is the relation of L to F on the surface of the terella, so is that of G to H on its orbe and of E to D on its orbe; also all the rotations on the orbes toward the termini of the orbes are such as they are on the surface of the terrella, or toward the termini of its surface. But if in the more remote orbes this fails somewhat at times, it happens on account of the sluggishness of the stone, or on account of the feebler forces due to the too great distance of the orbes from the terrella.



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Demonstration.

Set upon the instrumental diagram described farther back [chap. 3] a plate or stiff circle of brass or tin, on which may be described the magnetick orbes, as in the diagram above; and in the middle let a hole be made according to the size of the terrella, so that the plate may lie evenly on the wood about the middle of the terrella on a meridional circle. Then let a small versorium of the length of a barley-corn be placed on any orbe; upon which, when it is moved to various positions on the same circle, it will always pay regard to the dimensions of that orbe, not to those of the stone; as is shown in the diagram of the effused magnetick forms.

While some assign occult and hidden virtues of substances, others a property of matter, as the causes of the wonderful magnetical effects; we have discovered the primary substantive form of globes, not from a conjectural shadow of the truth of reasons variously controverted; but we have laid hold of the true efficient cause, as from many other demonstrations, so also from this most certain diagram of magnetick forces effused by the form. Though this (the form) has not been brought under any of our senses, and on that account is the less perceived by the intellect, it now appears manifest and conspicuous even to the eyes through this essential activity which proceeds from it as light from a lamp. And here it must be noted that a magnetick needle, moved on the top of the earth or of a terrella or of the effused orbes, makes two complete rotations in one circuit of its centre, like some epicycle about its orbit.

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CHAP. XII.

Magnetick force is animate, or imitates life; and in many things surpasses human life, while this is bound *up in the organick body.*

 loadstone is a wonderful thing in very many experiments, and like a living creature. And one of its remarkable virtues is that which the ancients considered to be a living soul in the sky, in the globes and in the stars, in the sun and in the moon. For they suspected that such various motions could not arise without a divine and animate nature, immense bodies turned about in fixed times, and wonderful powers infused into other bodies; whereby the whole universe flourishes in most beautiful variety, through this primary form of the globes themselves. The ancients, as Thales, Heraclitus, Anaxagoras, Archelaus, Pythagoras, Empedocles, Parmenides, Plato, and all the Platonists, and not only the older Greeks, but the Egyptians and Chaldæans, seek for some universal life in the universe, and affirm that the whole universe is endowed with life. Aristotle affirms that not the whole universe is animate, but only the sky; but he maintains that its elements are inanimate; whilst the stars themselves are animate. We, however, find this life in globes only and in their homogenic parts; and though it is not the same in all globes (for it is much more eminent in the sun and in certain stars than in others of less nobility) yet in very many the lives of the globes agree in their powers. For each several homogenic part draws to its own globe in a similar manner, and has an inclination to the common direction of the whole in the universe; and the effused forms extend outward in all, and are carried out into an orbe, and have bounds of their own; hence the order and regularity of the motions and rotations of all the planets, and their courses, not wandering away, but fixed and determined. Wherefore Aristotle concedes life to the sphæres themselves and to the orbes of the heavens (which he feigns), because they are suitable and fitted for a circular motion and actions, and are carried along in fixed and definite courses. It is surely wonderful, why the globe of the earth alone with its emanations is condemned by him and his followers and cast into exile (as senseless and lifeless), and driven out of all the perfection of the excellent universe. It is treated as a small corpuscle in comparison with the whole, and in the numerous concourse of many thousands it is obscure, disregarded, and unhonoured. With it also they {209} connect the kindred elements, in a like unhappiness, wretched and neglected. Let this therefore be looked upon as a monstrosity in the Aristotelian universe, in which everything is perfect, vigorous, animated; whilst the earth alone, an unhappy portion, is paltry, imperfect, dead, inanimate, and decadent. But on the other hand Hermes, Zoroaster, Orpheus, recognize a universal life. We, however, consider that the whole universe is animated, and that all the globes, all the stars, and also the noble earth have been governed since the beginning by their own appointed souls and have the motives of self-conservation. Nor are there wanting, either implanted in their homogenic nature or scattered through their homogenic substance, organs suitable for organic activity, although these are not fashioned of flesh and blood as animals, or composed of regular limbs, which are also hardly perceptible in certain plants and vegetables; since regular limbs are not necessary for all life. Nor can any organs be discerned or imagined by us in any of the stars, the sun, or the planets, which are specially operative in the universe; yet they live and imbue with life the small particles in the prominences on the earth. If there be anything of which men can boast, it is in fact life, intelligence; for the other animals are ennobled by life; God also (by whose nod all things are ruled) is a living soul. Who therefore will demand organs for the divine intelligences, which rise superior to every combination of organs and are not restrained by materialized organs? But in the several bodies of the stars the implanted force acts otherwise than in those divine existences which are supernaturally ordained; and in the stars, the sources of things, otherwise than in animals; in animals again otherwise than in plants. Miserable were the condition of the stars, abject the lot of the earth, if that wonderful dignity of life be denied to them, which is conceded to worms, ants, moths, plants, and toadstools; for thus worms, moths, grubs would be bodies more honoured and perfect in nature; for without life no body is excellent, valuable, or distinguished. But since living bodies arise and receive life from the earth and the sun, and grass grows on the earth apart from any seeds thrown down (as when soil is dug up from deep down in the earth, and put on some very high place or on a very high tower, in a sunny spot, not so long after various grasses spring up unbidden) it is not likely that they can produce what is not in them; but they awaken life, and therefore they are living. Therefore the bodies of the globes, as important parts of the universe, in order that they might be independent and that they might continue in that condition, had a need for souls to be united with them, without which there can be neither life, nor primary activity, nor motion, nor coalition, nor controlling power, nor harmony, nor endeavour, nor sympathy; and without which there would be no generation of anything, no alternations of the seasons, no propagation; but all things {210} would be carried this way and that, and the whole universe would fall into wretchedest Chaos, the earth in short would be vacant, dead, and useless. But it is only on the superficies of the globes that the concourse of living and animated beings is clearly perceived, in the great and pleasing variety of which the great master-workman is well pleased. But those souls which are restrained within a kind of barrier and in prison cells, as it were, do not emit immaterial effused forms outside the limits of their bodies; and bodies are not moved by them without labour and waste. They are brought and carried away by a breath; and when this has calmed down or been suppressed by some untoward influence, their bodies lie like the dregs of the universe and as the refuse of the globes. But the globes themselves remain and continue from year to year, move, and advance, and complete their courses, without waste or weariness. The human soul uses reason, sees many things, inquires about many more; but even the best instructed receives by his external senses (as through a lattice) light and the beginnings of knowledge. Hence come so many errors and follies, by which our judgments and the actions of our lives are perverted; so that few or none order their actions rightly and justly. But the magnetick force of the earth and the formate life or living form of the globes, without perception, without error, without injury from ills and diseases, so present with us, has an implanted activity, vigorous through the whole material mass, fixed, constant, directive, executive, governing, consentient; by which the generation and death of all things are carried on upon the surface. For, without that motion, by

which the daily revolution is performed, all earthly things around us would ever remain savage and neglected, and more than deserted and absolutely idle. But those motions in the sources of nature are not caused by thinking, by petty syllogisms, and theories, as human actions, which are wavering, imperfect, and undecided; but along with them reason, instruction, knowledge, discrimination have their origin, from which definite and determined actions arise, from the very foundations that have been laid and the very beginnings of the universe; which we, on account of the infirmity of our minds, cannot comprehend. Wherefore Thales, not without cause (as Aristotle relates in his book *De Anima*), held that the loadstone was animate, being a part and a choice offspring of its animate mother the earth.

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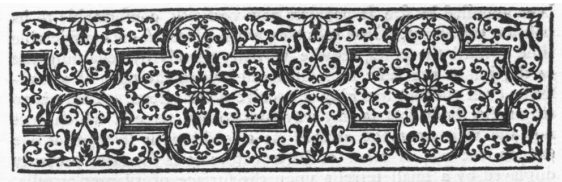


BOOK SIXTH.

CHAP. I.

ON THE GLOBE OF THE EARTH, THE *great magnet.*

Hitherto our subject hath been the loadstone and things magnetical: how they conspire together, and are acted upon, how they conform themselves to the terrella and to the earth. Now must we consider separately the globe itself of the earth. Those experiments which have been proved by means of the terrella, how magnetick things conform themselves to the terrella, are all or at least the principal and most important of them, displayed by means of the earth's Body: And to the earth things magnetical are in all respects associate. First, as in the terrella the æquator, meridians, parallels, axis, poles are natural boundaries, as numerous experiments make plain: So also in the earth these boundaries are natural, not mathematical only (as all before us used to suppose). These boundaries the same experiments display and establish in both cases alike, in the earth no less than in the terrella. Just as on the periphery of a terrella a loadstone or a magnetick piece of iron is directed to its proper pole: so on the earth's surface are there turnings-about, peculiar, manifest, and constant on either side of the æquator. Iron is indued with verticity by being extended toward a pole of the earth, just as toward a pole of the terrella: By its being placed down also, and cooling toward the earth's pole after the pristine verticity has been annulled by fire, it acquires new verticity, {212} conformable to its position earthward. Iron rods also, when placed some considerable time toward the poles, acquire verticity merely by regarding the earth; just as the same rods, if placed toward the pole of a loadstone, even without touching it, receive polar virtue. There is no magnetick body that in any way runs to the terrella which does not also wait upon the earth. As a loadstone is stronger at one end on one side or other[240] of its æquator: so is the same property displayed by a small terrella upon the surface of a larger terrella. According to the variety and artistick skill in the rubbing of the magnetick iron upon the terrella, so do the magnetick things perform their function more efficiently or more feebly. In motions toward the earth's body, as toward the terrella a variation is displayed due to the unlikeness, inequality, and imperfection of its eminences: So every variation of the versorium or mariners' compass, everywhere by land or by sea, which thing has so sorely disturbed men's minds, is discerned and recognized as due to the same causes. The magnetick dip (which is the wonderful turning of magnetick things to the body of the terrella) in systematick course, is seen in clearer light to be the same thing upon the earth. And that single experiment, by a wonderful indication, as with a finger, proclaims the grand magnetick nature of the earth to be innate and diffused through all her inward parts. A magnetick vigour exists then in the earth just as in the terrella, which is a part of the earth, homogenic in nature with it, but rounded by Art, so as to correspond with the earth's globous shape and in order that in the chief experiments it might accord with the globe of the earth.

CHAP. II.

The Magnetick axis of the Earth *persists invariable.*

As in the very first beginnings of the moving world, the earth's magnetick axis passed through the midst of the earth: so now it tends through the centre to the same points of the superficies; the circle and plane of the æquinoctial line also persisting. For not without the vastest overthrow of the terrene mass can these natural boundaries be changed, as it is easy to gather from magnetick demonstrations. Wherfore the opinion of Dominicus Maria of Ferrara, a most talented man, who was the teacher of Nicolas Copernicus, must be cancelled; a view which, according to certain observations of his own, is as follows.[241] {213} "I," he says, "in former years while studying Ptolemy's *Geographia* discovered that the elevations of the North pole placed by him in the several regions, fall short of what they are in our time by one degree and ten minutes: which divergence can by no means be ascribed to an error of the tables: For it is not credible that the whole series in the book is equally wrong in the figures of the tables: Hence it is necessary to allow that the North pole has been tilted toward the vertical point. Accordingly a lengthy observation has already begun to disclose to us things hidden from our forefathers; not indeed through any sloth of theirs, but because they lacked the prolonged observation of their predecessors: For before Ptolemy very few places were observed with regard to the elevations of the pole, as he himself also bears witness at the beginning of his *Cosmographia*: (For, says he) Hipparchus alone hath handed down to us the latitudes of a few places, but a good many have noted those of distances; especially those which lie toward sunrise or sunset were received by some general tradition, not owing to any sloth on the part of authors themselves, but to the fact that there was as yet no practice of more exact mathematicks. 'Tis accordingly no wonder, if our predecessors did not mark this very slow motion: For in one thousand and seventy years it shows itself to be displaced scarce one degree toward the apex of dwellers upon the earth. The strait of Gibraltar shows this, where in Ptolemy's time the North pole appears elevated 36 degrees and a quarter from the Horizon: whereas now it is 37 and two-fifths. The like divergence is also shown at Leucopetra in Calabria, and at particular spots in Italy, namely those which have not changed from Ptolemy's time to our own. And so by reason of this movement, places now inhabited will some day become deserted, while those regions which are now parched at the torrid zone will, though long hence, be reduced to our temper of climate. Thus, as in a course of three hundred and ninety five thousands of years, is that very slow movement completed." Thus, according to these observations of Dominicus Maria, the North pole is at a higher elevation, and the latitudes of places are greater than formerly; whence he argues a change of latitudes. Now, however, Stadius, taking just the contrary view, proves by observations that the latitudes have decreased. For he says: "The latitude of Rome in Ptolemy's *Geographia* is 41 degrees ⅔: and that you may not suppose any error of reckoning to have crept in on the part of Ptolemy, on the day of the Æquinox in the city of Rome, the ninth part of the gnomon of the sun-dial is lacking in shadow, as Pliny relates and Vitruvius witnesseth in his ninth book." But the observation of moderns (according to Erasmus Rheinholdus) gives the same in our time as 41 degrees with a sixth: so that you are in doubt as to half of one degree in the centre of the world, {214} whether you show it to have decreased by the earth's obliquity of motion. One may see then how from inexact observations men rashly conceive new and contradictory opinions and imagine absurd motions of the mechanism of the earth. For since Ptolemy only received certain latitudes from Hipparchus, and did not in very many places make the observations himself; it is likely that he himself, knowing the position of the places, formed his estimate of the latitude of cities from probable conjecture only, and then placed it in the maps. Thus one may see, in the case of our own Britain, that the latitudes of cities are wrong by two or three degrees, as experience teaches. Wherefore all the less should we from those mistakes infer a new motion, or let the noble magnetick nature of the earth be debased for an opinion so lightly conceived. Moreover, those mistakes crept the more readily into geography, from the fact that the magnetick virtue was utterly unknown to those geographers. Besides, observations of latitudes cannot be made sufficiently exactly, except by experts, using also finer instruments, and taking into account the refraction of the lights.

CHAP. III.

On the magnetick diurnal revolution of the Earth's globe, as a probable assertion against the time-honoured *opinion of a Primum Mobile*.

Among the ancients Heraclides of Pontus and Ecphantus, afterwards the Pythagoreans, as Nicetas of Syracuse and Aristarchus of Samos, and some others (as it seems), used to think that the earth moves, and that the stars set by the interposition of the earth and rose by her retirement. In fact they set the earth moving and make her revolve around her axis from west to east, like a wheel turning on its axle. Philolaus the Pythagorean[242] would have the earth to be one of the stars, and believed that it turned in an oblique circle around fire, just as the sun and moon have their own courses. He was a distinguished mathematician, and a most able investigator of nature. But after Philosophy became a subject treated of by very many and was popularized, theories adapted to the vulgar

intelligence or based on sophistical subtility occupied the minds of most men, and prevailed like a torrent, the multitude consenting. Thereupon many valuable discoveries of the ancients were rejected, and were dismissed to perish in banishment; or at least by not being further cultivated and developed became obsolete. So that Copernicus[243] (among later discoverers, a man most deserving of literary honour) is the first who attempted to illustrate the φαινόμενα of moving {215}
bodies by new hypotheses: and these demonstrations of reasons others either follow or observe in order that they may more surely discover the phænomenal harmony of the movements; being men of the highest attainments in every kind of learning. Thus supposed and imaginary orbs of Ptolemy and others for finding the times and periods of the motions are not necessarily to be admitted to the physical inquiries of philosophers. It is then an ancient opinion and one that has come down from old times, but is now augmented by important considerations that the whole earth rotates with a daily revolution in the space of 24 hours. Well then, since we see the Sun and Moon and other planets and the glory of all the stars approach and retire within the space of one natural day, either the Earth herself must needs be set in motion with a diurnal movement from West to East, or the whole heaven and the rest of nature from East to West. But, in the first place, it is not likely that the highest heaven and all those visible splendours of the fixed stars are impelled along that most rapid and useless course. Besides, who is the Master who has ever made out that the stars which we call fixed are in one and the same sphere, or has established by reasoning that there are any real and, as it were, adamantine sphæres? No one has ever proved this as a fact; nor is there a doubt but that just as the planets are at unequal distances from the earth, [244]so are those vast and multitudinous lights separated from the Earth by varying and very remote altitudes; they are not set in any sphærick frame or firmament (as is feigned), nor in any vaulted body: accordingly the intervals of some are from their unfathomable distance matter of opinion rather than of verification; others do much exceed them and are very far remote, and these being located in the heaven at varying distances, either in the thinnest æther or in that most subtile quintessence, or in the void: how are they to remain in their position during such a mighty swirl of the vast orbe of such uncertain substance. There have been observed by astronomers 1022 stars; besides these, numberless others are visible, some indeed faint to our senses, in the case of others our sense is dim and they are hardly perceived and only by exceptionally keen eyes, and there is no one gifted with excellent sight who does not when the Moon is dark and the air at its rarest, discern numbers and numbers dim and wavering with minute lights on account of the great distance: hence it is credible both that these are many and that they are never all included in any range of vision. How immeasurable then must be the space which stretches to those remotest of fixed stars! How vast and immense the depth of that imaginary sphere! How far removed from the Earth must the most widely separated stars be and at a distance transcending all sight, all skill and thought! How monstrous then such a motion would be! It is evident then that all the heavenly bodies set as if in destined places are there {216}
formed into sphæres, that they tend to their own centres, and that round them there is a confluence of all their parts. And if they have motion, that motion will rather be that of each round its own centre, as that of the Earth is; or a forward movement of the centre in an orbit, as that of the Moon: there would not be circular motion in the case of a too numerous and scattered flock. Of these stars some situate near the Æquator would seem to be borne around at a very rapid rate, others nearer the pole to have a somewhat gentler motion, others, apparently motionless, to have a slight rotation. Yet no differences in point of light, mass or colours are apparent to us: for they are as brilliant, clear, glittering and duskish toward the poles, as they are near the Æquator and the Zodiack: those which remain set in those positions do not hang, and are neither fixed, nor bound to anything of the nature of a vault. All the more insane were the circumvolution of that fictitious *Primum Mobile*, which is higher, deeper, and still more immeasurable. Moreover, this inconceivable *Primum Mobile* ought to be material and of enormous depth, far surpassing all inferior nature in size: for nohow else could it conduct from East to West so many and such vast bodies of stars, and the universe even down to the Earth: and it requires us to accept in the government of the stars a universal power and a despotism perpetual and intensely irksome. That *Primum Mobile* bears no visible body, is nohow recognizable, is a fiction believed in by those people, accepted by the weak-minded folk, who wonder more at our terrestrial mass than at bodies so vast, so inconceivable, and so far separated from us. But there can be no movement of infinity and of an infinite body, and therefore no diurnal revolution of that vastest *Primum Mobile*. The Moon being neighbour to the Earth revolves in 27 days; Mercury and Venus have their own moderately slow motions; Mars finishes a period in two years, Jupiter in twelve years, Saturn in thirty. And those also who ascribe a motion to the fixed stars make out that it is completed in 36,000 years, according to Ptolemy, in 25,816 years, according to Copernicus' observations; so that the motion and the completion of the journey always become slower in the case of the greater circles. And would there then be a diurnal motion of that *Primum Mobile* which is so great and beyond them all immense and profound? 'Tis indeed a superstition and in the view of philosophy a fable now only to be believed by idiots, deserving more than ridicule from the learned: and yet in former ages, that motion, under the pressure of an importunate mob of philosophizers, was actually accepted as a basis of computations and of motions, by mathematicians. The motions of the bodies (namely planets) seem to take place eastward and following the order of the signs. The common run of {217}
mathematicians and philosophers also suppose that the fixed stars in the same manner advance with a very slow motion: and from ignorance of the truth they are forced to join to them a ninth sphære. Whereas now this first and unthinkable *Primum Mobile*, a fiction not comprehended by any judgment, not evidenced by any visible constellation, but devised of imagination only and mathematical hypothesis, unfortunately accepted and believed by philosophers, extended into the heaven and beyond all the stars, must needs with a contrary impulse turn about from East to

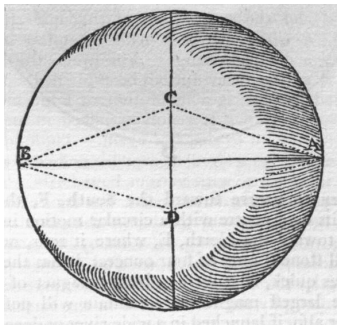
West, in opposition to the inclination of all the rest of the Universe. Whatsoever in nature is moved naturally, the same is set in motion both by its own forces and by the consentient compact of other bodies. Such is the motion of parts to their whole, of all interdependent sphæres and stars in the universe: such is the circular impulse in the bodies of the planets, when they affect and incite one another's courses. But with regard to the *Primum Mobile* and its contrary and exceeding rapid movement, what are the bodies which incite it or propel it? What is the nature that conspires with it? Or what is that mad force beyond the *Primum Mobile*? Since it is in bodies themselves that acting force resides, not in spaces or intervals. But he who thinks that those bodies are at leisure and keeping holiday, while all the virtue of the universe appertains to the very orbits and sphæres, is on this point not less mad than he who, in some one else's house, thinks that the walls and floors and roof rule the family rather than the wife and thoughtful paterfamilias. Therefore not by the firmament are they borne along, or are moved, or have their position; much less are those confused crowds of stars whirled around by the *Primum Mobile*, nor are they torn away and huddled along by a contrary and extremely rapid movement. Ptolemy of Alexandria seems to be too timid and weak-minded in dreading the dissolution of this nether world, were the Earth to be moved round in a circle. Why does he not fear the ruin of the Universe, dissolution, confusion, conflagration, and infinite disasters celestial and super-celestial, from a motion transcending all thoughts, dreams, fables, and poetic licences, insurmountable, ineffable, and inconceivable? Wherefore we are carried along by a diurnal rotation of the earth (a motion for sure more congruous), and as a boat moves above the waters, so do we turn about with the earth, and yet seem to ourselves to be stationary, and at rest. Great and incredible it seems to some philosophers, by reason of inveterate prejudice, that the Earth's vast body should be swirled wholly round in the space of 24 hours. But it would be more incredible that the Moon should travel through her orbit, or complete an entire course in a space of 24 hours; more so the Sun or Mars; still more Jupiter and Saturn; more than marvellous would be the velocity in the case of the fixed stars and the firmament; what in the world they would have to wonder at in the {218}
case of their ninth sphere, let them imagine as they like. But to feign a *Primum Mobile* and to attribute to the thing thus feigned a motion to be completed in the space of 24 hours, and not to allow this motion to the Earth in the same interval of time, is absurd. For a great circle of the Earth is to the ambit of the *Primum Mobile* less than a furlong to the whole Earth. If the diurnal rotation of the Earth seem headlong, and not admissible in nature by reason of its rapidity, worse than insane will be the movement of the *Primum Mobile* both for itself and the whole universe, agreeing as it does with no other motion in any proportion or likeness. It seems to Ptolemy and the Peripateticks that nature must be disordered, and the framework and structure of this globe of ours be dissolved, by reason of so swift a terrestrial revolution. The Earth's diameter is 1718 German miles; the greatest elongation of the new Moon is 65, the least is 55 semi-diameters of the Earth: the greatest altitude of the half moon is 68, the least 52: yet it is probable that its sphære is still larger and deeper. The sun in its greatest eccentricity has a distance of 1142 semi-diameters of the Earth; Mars, Jupiter, Saturn, being slower in motion, are so proportionately further remote from the Earth. The distances of the firmament and of the fixed stars seem to the best mathematicians inconceivable. Leaving out the ninth sphære, if the convexity of the *Primum Mobile* be duly estimated in proportion to the rest of the sphæres, the vault of the *Primum Mobile* must in one hour run through as much space as is comprised in 3000 great circles of the Earth, for in the vault of the firmament it would complete more than 1800; but what iron solidity can be imagined so firm and tough as not to be disrupted and shattered to fragments by a fury so great and a velocity so ineffable. The Chaldæans indeed would have it that the heaven consists of light. In light, however, there is no so-great firmness, neither is there in Plotinus' fiery firmament, nor in the fluid or aqueous or supremely rare and transparent heaven of the divine Moses, which does not cut off from our sight the lights of the stars. We must accordingly reject the so deep-set error about this so mad and furious a celestial velocity, and the forced retardation of the rest of the heavens. Let theologians discard and wipe out with sponges those old women's tales of so rapid a spinning round of the heavens borrowed from certain inconsiderate philosophers. The sun is not propelled by the sphære of Mars (if a sphære there be) and by his motion, nor Mars by Jupiter, nor Jupiter by Saturn. The sphære, too, of the fixed stars, seems well enough regulated except so far as motions which are in the Earth are ascribed to the heavens, and bring about a certain change of phænomena. The superiors do not exercise a despotism over the inferiors; for the heaven of philosophers, as of theologians, must be gentle, happy, and tranquil, and not at all {219}
subject to changes: nor shall the force, fury, swiftness, and hurry of a *Primum Mobile* have dominion over it. That fury descends through all the celestial sphæres, and celestial bodies, invades the elements of our philosophers, sweeps fire along, rolls along the air, or at least draws the chief part of it, conducts the universal æther, and turns about fiery impressions (as if it were a solid and firm body, when in fact it is a most refined essence, neither resisting nor drawing), leads captive the superior. O marvellous constancy of the terrestrial globe, the only one unconquered; and yet one that is holden fast, or stationary, in its place by no bonds, no heaviness, by no contiguity with a grosser or firmer body, by no weights. The substance of the terrestrial globe withstands and sets itself against universal nature. Aristotle feigns for himself a system of philosophy founded on motions simple and compound, that the heavens revolve in a simple circle, its elements moving with a right motion, the parts of the earth seeking the earth in straight lines, falling on its surface at right angles, and tending together toward its centre, always, however, at rest therein; accordingly also the whole Earth remains immovable in its place, united and compacted together by its own weight. That cohæsion of parts and aggregation of matter exist in the Sun, in the Moon, in the planets, in the fixed stars, in fine in all those round bodies whose parts cohære together and tend each to their own centres; otherwise the heaven would fall, and that sublime ordering would be lost: yet these cœlestial bodies have a circular motion. Whence the Earth too may equally have her own motion: and this motion is not (as some

deem it) unsuitable for the assembling or adverse to the generation of things. For since it is innate in the terrestrial globe, and natural to it; and since there is nothing external that can shock it, or hinder it by adverse motions, it goes round without any ill or danger, it advances without being forced, there is nothing that resists, nothing that by retiring gives way, but all is open. For while it revolves in a space void of bodies, or in the incorporeal æther, all the air, the exhalations of land and water, the clouds and pendent meteors, are impelled along with the globe circularly: that which is above the exhalations is void of bodies: the finest bodies and those which are least cohærent almost void are not impeded, are not dissolved, while passing through it. Wherefore also the whole terrestrial globe, with all its adjuncts, moves bodily along, calmly, meeting no resistance. Wherefore empty and superstitious is the fear that some weak minds have of a shock of bodies (like Lucius Lactantius, who, in the fashion of the unlettered rabble and of the most unreasonable men scoffs at an Antipodes and at the sphærick ordering of the Earth all round). So for these reasons, not only probable but manifest, does the diurnal rotation of the earth seem, since nature always acts through a few rather than through many; and it is more {220} agreeable to reason that the Earth's one small body should make a diurnal rotation, than that the whole universe should be whirled around. I pass over the reasons of the Earth's remaining motions, for at present the only question is concerning its diurnal movement, according to which it moves round with respect to the Sun, and creates a natural day (which we call a nycthemeron[245]). And indeed Nature may be thought to have granted a motion very suitable to the Earth's shape, which (being sphærical) is revolved about the poles assigned it by Nature much more easily and fittingly than that the whole universe, whose limit is unknown and unknowable, should be whirled round; and than there could be imagined an orbit of the *Primum Mobile*, a thing not accepted by the ancients, which Aristotle even did not devise or accept as in any shape or form existing beyond the sphære of the fixed stars; which finally the sacred scriptures do not recognize any more than they do the revolution of the firmament.

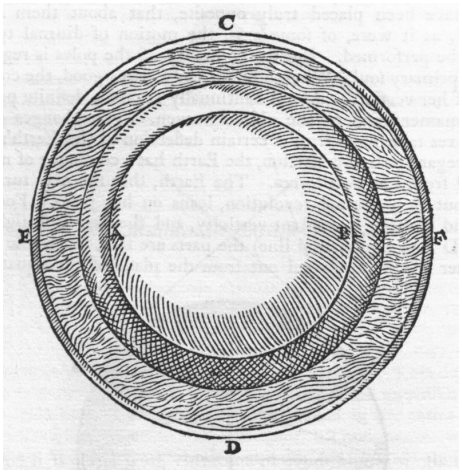
CHAP. IIII.

That the Earth moves circularly.

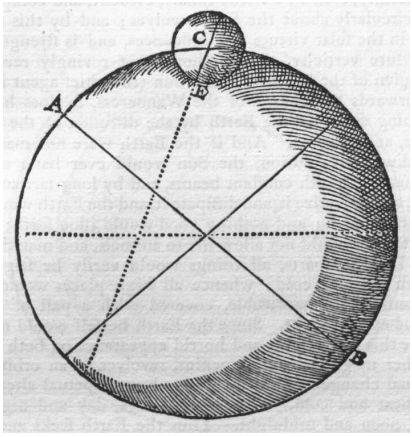
If then the philosophers of the common sort, with an unspeakable absurdity, imagine the whole heaven and the vast extent of the universe to rotate in a whirl, it yet remains that the earth performs a diurnal change. For in no third way can the apparent revolutions be explained. This day, then, which is called natural, is a revolution of some meridian of the Earth from Sun to Sun. It revolves indeed in an entire course, from a fixed star round to that star again. Those bodies which in nature are moved with a circular, æquable and constant motion, are furnished, in their parts, with various boundaries. But the Earth is not a Chaos nor disordered mass; but by reason of its astral virtue, it has boundaries which subserve the circular motion, poles not mathematical, an æquator not devised by imagination, meridians also and parallels; all of which we find permanent, certain and natural in the Earth: which by numerous experiments the whole magnetick philosophy sets forth. For in the earth there are poles set in fixed bounds, and at them the verticity mounts up on either side from the plane of the Earth's æquator, with forces which are mightier and præpotent from the common action of the whole; and with these poles the diurnal revolution is in agreement. But in no turnings-about of bodies, in none of the motions of the planets are there to be recognized, beheld, or assured to us by any reasoning any sensible or natural poles in the firmament, or in any *Primum Mobile*; but those are the conception of an unsettled imagination. Wherefore we, {221} following an evident, sensible and tested cause, do know that the earth moves on its own poles, which are apparent to us by many magnetick demonstrations. For not only on the ground of its constancy, and its sure and permanent position, is the Earth endowed with poles and verticity: for it might be directed toward other parts of the universe, toward East or West or some other region. By the wondrous wisdom then of the Builder forces, primarily animate, have been implanted in the Earth, that with determinate constancy the Earth may take its direction, and the poles have been placed truly opposite[246], that about them as the termini, as it were, of some axis, the motion of diurnal turning might be performed. But the constancy of the poles is regulated by the primary soul. Wherefore, for the Earth's good, the collimations of her verticities do not continually regard a definite point of the firmament and of the visible heaven. For changes of the æquinoxes take place from a certain deflection of the Earth's axis; yet in regard to that deflection, the Earth has a constancy of motion derived from her own forces. The Earth, that she may turn herself about in a diurnal revolution, leans on her poles. For since at A and B there is constant verticity, and the axis is straight; at C and D (the æquinoctial line) the parts are free, the whole forces on either side being spread out from the plane of the æquator toward the poles, in æther which is free from renitency, or else in a void; and A and B remaining constant, C revolves toward D both from innate conformity and aptitude, and for necessary good, and the avoidance of evil; but being chiefly moved forward by the diffusion of the solar orbes of virtues, and by their lights. And 'tis borne around, not upon a new and strange course, but (with the tendency common to the {222} rest of the planets) it tends from West to East. For all planets have



a like motion Eastward according to the succession of the signs, whether Mercury and Venus revolve beneath the Sun, or around the Sun. That the Earth is capable of and fitted for moving circularly its parts show, which when separated from the whole are not only borne along with the



straight movement taught by the Peripateticks, but rotate also. A loadstone fixed in a wooden vessel is placed on water so as to swim freely, turn itself, and float about. If the pole B of the loadstone be set contrary to nature toward the South, F, the Terrella is turned about its own centre with a circular motion in the plane of the Horizon, toward the North, E, where it rests, not at C or D. So does a small stone if only of four ounces; it has the same motion also and just as quick, if it were a strong magnet of one hundred pounds. The largest magnetical mountain will possess the same turning-power also, if launched in a wide river or deep sea: and yet a magnetick body is much more hindered by water than the whole Earth is by the æther. The whole Earth would do the same, if the Boreal pole were to be diverted from its true direction; for the Boreal pole would run back with the circular motion of the whole around the centre toward the Cynosure. But this motion by which the parts naturally settle themselves in their own resting-places is no other than circular. The whole Earth regards the Cynosure with her {223}
pole according to a steadfast law of her nature: and thus each true part of it seeks a like resting-place in the world, and is moved circularly toward that position. The natural movements of the whole and of the parts are alike: wherefore when the parts are moved in a circle, the whole also has the potency of moving circularly. A sphærical loadstone placed in a vessel on water moves circularly around its centre (as is manifest) in the plane of the Horizon, into conformity[247] with the earth.



So also it would move in any other great circle if it could be free; as in the declination instrument, a circular motion takes place in the meridian (if there were no variation), or, if there should be some variation, in a great circle drawn from the Zenith through the point of variation on the horizon. And that circular motion of the magnet to its own just and natural position shows that the whole Earth is fitted and adapted, and is sufficiently furnished with peculiar forces for diurnal circular motion. I omit what Peter Peregrinus[248] constantly affirms, that a terrella suspended above its poles on a meridian moves circularly, making an entire revolution in 24 hours: which, however, it has not happened to ourselves as yet to see; and we even doubt this motion on account of the weight of the stone itself, as well as because the whole Earth, as she is moved of herself, so also is she propelled by other stars: and this does not happen in proportion (as it does in the terrella) in every part. The Earth is moved by {224}
her own primary form and natural desire, for the conservation, perfection, and ordering of its parts, toward things more excellent: and this is more likely than that the fixed stars, those luminous globes, as well as the Wanderers, and the most glorious and divine Sun, which are in no way aided by the Earth, or renewed, or urged by any virtue therein, should circulate aimlessly around the Earth, and that the whole heavenly host should repeat around the Earth courses never ending and of no profit whatever to the stars. The Earth, then, which by some great necessity, even by a virtue innate, evident, and conspicuous, is turned circularly about the Sun, revolves; and by this motion it rejoices in the solar virtues and influences, and is strengthened by its own sure verticity, that it should not rovingly revolve over every region of the heavens. The Sun (the chief agent in nature) as he forwards the courses of the Wanderers, so does he prompt this turning about of the Earth by the diffusion of the virtues of his orbes, and of light. And if the Earth were not made to spin with a diurnal revolution, the Sun would ever hang over some determinate part with constant beams, and by long tarriance would scorch it, and pulverize it, and dissipate it, and the Earth would sustain the deepest wounds; and nothing good would issue forth; it would not vegetate, it would not allow life to animals, and mankind would perish. In other parts, all things would verily be frightful and stark with extreme cold; whence all high places would be very rough, unfruitful, inaccessible, covered with a pall of perpetual shades and eternal night. Since the Earth herself would not choose to endure this so miserable and horrid appearance on both her faces, she, by her magnetick astral genius, revolves in an orbit, that by a perpetual change of light there may be a perpetual alternation of things, heat and cold, risings and settings, day and night, morn and eve, noon and midnight. Thus the Earth seeks and re-seeks the Sun, turns away from him and pursues him, by her own wondrous magnetick virtue. Besides, it is not only from the Sun that evil would impend, if the Earth were to stay still and be deprived of solar benefit; but from the Moon also serious dangers would threaten. For we see how the ocean rises and swells beneath certain known positions of the Moon: And if there were not through the daily rotation of Earth a speedy transit of the Moon, the flowing sea would be driven above its level into certain regions, and many shores would be overwhelmed with huge waves. In order then that Earth may not perish in various ways, and be brought to confusion, she turns herself about by magnetick and primary virtue: and the like motions exist also in the rest of the Wanderers, urged specially by the movement and light of other bodies. For the Moon also turns

herself about in a monthly course, to receive in succession the Sun's beams in which she, like the Earth, rejoices, and is refreshed: nor could she endure them for ever on one particular side {225} without great harm and sure destruction. Thus each one of the moving globes is for its own safety borne in an orbit either in some wider circle, or only by a rotation of its body, or by both together. But it is ridiculous for a man a philosopher to suppose that all the fixed stars and the planets and the still higher heavens revolve to no other purpose, save the advantage of the Earth. It is the Earth, then, that revolves, not the whole heaven, and this motion gives opportunity for the growth and decrease of things, and for the generating of things animate, and awakens internal heat for the bringing of them to birth. Whence matter is quickened for receiving forms; and from the primary rotation of the Earth natural bodies have their primary impetus and original activity. The motion then of the whole Earth is primary, astral, circular, around its own poles, whose verticity arises on both sides from the plane of the æquator, and whose vigour is infused into opposite termini, in order that the Earth may be moved by a sure rotation for its good, the Sun also and the stars helping its motion. But the simple straight motion downwards of the Peripateticks is a motion of weight, a motion of the aggregation of disjoined parts, in the ratio of their matter, along straight lines toward the body of the Earth: which lines tend the shortest way toward the centre. The motions of disjoined magnetical parts of the Earth, besides the motion of aggregation, are coition, revolution, and the direction of the parts to the whole, for harmony of form, and concordancy.

CHAP. V.

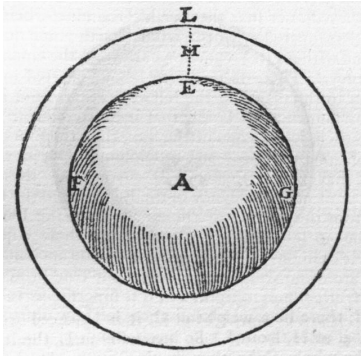
Arguments of those denying the Earth's motion, and *their confutation.*

Now it will not be superfluous to weigh well the arguments of those who say the Earth does not move; that we may be better able to satisfy the crowd of philosophizers who assert that this constancy and stability of the Earth is confirmed by the most convincing arguments. Aristotle does not allow that the Earth moves circularly, on the ground that each several part of it would be affected by this particular motion; that whereas now all the separate parts of the Earth are borne toward the middle in straight lines, that circular motion would be violent, and strange to nature, and not enduring. But it has been before proved that all actual portions of the Earth move in a circle, and that all magnetick bodies (fitly disposed) are borne around in an orbe. They are borne, however, toward the centre of the Earth in a straight line (if the way be open) by a motion of aggregation as though to their own {226} origin: they move by various motions agreeably to the conformation of the whole: a terrella is moved circularly by its innate forces. "Besides" (says he), "all things which are borne in an orbe, afterwards would seem to be abandoned by the first motion, and to be borne by several motions besides the first. The Earth must also be borne on by two sorts of motion, whether it be situate around a mid-point, or in the middle site of the universe: and if this were so, there must needs be at one time an advance, at another time a retrogression of the fixed stars: This, however, does not seem to be the case, but they rise and set always the same in the same places." But it by no means follows that a double motion must be assigned to the Earth. But if there be but one diurnal motion of the Earth around its poles, who does not see that the stars must always in the same manner rise and set at the same points of the horizon, even although there be another motion about which we are not disputing: since the mutations in the smaller orbit cause no variation of aspect in the fixed stars owing to their great distance, unless the axis of the Earth have varied its position, concerning which we raise a question when speaking of the cause of the præcession of the æquinoxes. In this argument are many flaws. For if the Earth revolve, that we asserted must needs occur not by reason of the first sphære, but of its innate forces. But if it were set in motion by the first sphære, there would be no successions of days and nights, for it would continue its course along with the *Primum Mobile*. But that the Earth is affected by a double movement at the time when it rotates around its own centre, because the rest of the stars move with a double motion, does not follow. Besides, he does not well consider the argument, nor do his interpreters understand the same. τούτου δὲ συμβαίνοντος, ἀναγκαῖον γίγνεσθαι παρόδους καὶ τροπὰς τῶν ἐνδεδεμένων ἄστρων. (Arist. *de Cœlo*, ii. chap. 14.) That is, "If this be so, there must needs be changes, and retrogressions of the fixed stars." What some interpret as retrogressions or regressions, and changes of the fixed stars, others explain as diversions: which terms can in no way be understood of axial motion, unless he meant that the Earth moved by the *Primum Mobile* is borne and turned over other poles diverse even from those which correspond to the first sphære, which is altogether absurd. Other later theorists suppose that the eastern ocean ought to be impelled so into western regions by that motion, that those parts of the Earth which are dry and free from water would be daily flooded by the eastern ocean. But the ocean is not acted upon by that movement, since nothing opposes it; and even the whole atmosphere is carried round: And for that reason in the Earth's course all the things in the air are not left behind by us nor do they seem to move toward the West: Wherefore also the clouds are at rest in the air, unless the {227} force of the winds drive them; and objects which are projected into the air fall again into their own place. But those foolish folk who think that towers, temples, and buildings must necessarily be shaken and overthrown by the Earth's motion, may fear lest men at the Antipodes should slip off into an opposite orbe, or that ships when sailing round the entire [249]globe should (as soon as they have dipped under the plane of our horizon) fall into the opposite region of the sky. But

those follies are old wives' gossip, and the rubbish of certain philosophizers, men who, when they essay to treat of the highest truths and the fabrick of the universe, and hazard anything, can scarce understand aught *ultra crepidam*. They would have the Earth to be the centre of a circle; and therefore to rest motionless amid the rotation. But neither the stars nor the wandering globes move about the Earth's centre: the high heaven also does not move circularly round the Earth's centre; nor if the Earth were in the centre, is it a centre itself, but a body around a centre. Nor is it confident with reason that the heavenly bodies of the Peripateticks should attend on a centre so decadent and perishable as that of the Earth. They think that Nature seeks rest for the generation of things, and for promoting their increase while growing; and that accordingly the whole Earth is at rest. And yet all generation takes place from motion, without which the universal nature of things would become torpid. The motion of the Sun, the motion of the Moon, cause changes; the motion of the Earth awakens the internal breath of the globe; animals themselves do not live without motion, and the ceaseless activity of the heart and arteries. For of no moment are the arguments for a simple straight motion toward the centre, that this is the only kind in the Earth, and that in a simple body there is one motion only and that a simple one. For that straight motion is only a tendency toward their own origin, not of the parts of the Earth only, but of those of the Sun also, of the Moon, and of the rest of the sphæres which also move in an orbit. Joannes Costæus, who raises doubts concerning the cause of the Earth's motion, looking for it externally and internally, understands magnetick vigour to be internal, active, and disponent; also that the Sun is an external promotive cause, and that the Earth is not so vile and abject a body as it is generally considered. Accordingly there is a diurnal movement on the part of the Earth for its own sake and for its advantage. Those who make out that that terrestrial motion (if such there be) takes place not only in longitude, but also in latitude, talk nonsense. For Nature has set in the Earth determinate poles, and definite unconfused revolutions. Thus the Moon revolves with respect to the Sun in a monthly course; yet having her own definite poles, facing determinate parts of the heaven. To suppose that the air moves the Earth would be ridiculous. For air is only exhalation, and is an enveloping effluvium from the Earth itself; the {228}
winds also are only a rush of the exhalations in some part near the Earth's surface; the height of its motion is slight, and in all regions there are various winds unlike and contrary. Some writers, not finding in the matter of the Earth the cause (for they say that they find nothing except solidity and consistency), deny it to be in its form; and they only admit as qualities of the Earth cold and dryness, which are unable to move the Earth. The Stoicks attribute a soul to the Earth, whence they pronounce (amid the laughter of the learned) the Earth to be an animal. This magnetick form, whether vigour or soul, is astral. Let the learned lament and bewail the fact that none of those old Peripateticks, nor even those common philosophizers heretofore, nor Joannes Costæus, who mocks at such things, were able to apprehend this grand and important natural fact. But as to the notion that surface inequality of mountains and valleys would prevent the Earth's diurnal revolution, there is nothing in it: for they do not mar the Earth's roundness, being but slight excrescences compared with the whole Earth; nor does the Earth revolve alone without its emanations. Beyond the emanations, there is no renitency. There is no more labour exerted in the Earth's motion than in the march of the rest of the Stars: nor is it excelled in dignity by some stars. To say that it is frivolous to suppose that the Earth rather seeks a view of the Sun, than the Sun of the Earth, is a mark of great obstinacy and unwisdom. Of the theory of the rotation we have often spoken. If anyone seek the cause of the revolution, or of other tendency of the Earth, from the sea surrounding it, or from the motion of the air, or from the Earth's gravity, he would be no less silly as a theorist than those who stubbornly ground their opinions on the sentiments of the ancients. Ptolemy's reasonings are of no weight; for when our true principles are laid down, the truth comes to light, and it is superfluous to refute them. Let Costæus recognize and philosophers see how unfruitful and vain a thing it becomes then to take one's stand on the principles and unproved opinions of certain ancients. Some raise a doubt how it can be that, if the Earth move round its own axis, a globe of iron or of lead dropped from the highest point of a tower falls exactly perpendicularly to a spot of the Earth below itself. Also how it is that cannon balls from a large culverin, fired with the same quantity and strength of powder, in the same direction and at a like elevation through the same air, would be cast at a like distance from a given spot both Eastward and Westward, supposing the Earth to move Eastward. But those who bring forward this kind of argument are being misled: not attending to the nature of primary globes, and the combination of parts with their globes, even though they be not adjoined by solid parts. Whereas the motion of the Earth in the diurnal revolution does not involve the separation of her more solid circumference from the surrounding bodies; but all her effluvia surround her, {229}
and in them heavy bodies projected in any way by force, move on uniformly along with the Earth in general coherence. And this also takes place in all primary bodies, the Sun, the Moon, the Earth, the parts betaking themselves to their first origins and sources, with which they connect themselves with the same appetence as terrene things, which we call heavy, with the Earth. So lunar things tend to the Moon, solar things to the Sun, within the orbes of their own effluvia. The emanations hold together by continuity of substance, and heavy bodies are also united with the Earth by their own gravity, and move on together in the general motion: especially when there is no renitency of bodies in the way. And for this cause, on account of the Earth's diurnal revolution, bodies are neither set in motion, nor retarded; they do not overtake it, nor do they fall short behind it when violently projected toward East or West.

Let E F G be the Earth's globe, A its centre, L E the ascending effluvia: Just as the orbe of the effluvia progresses with the Earth, so also does the unmoved part of the circle at the straight line L E progress along with the general revolution. At L and E, a heavy body, M, falls perpendicularly toward E, taking the shortest way to the centre, nor is that right movement of weight, or of aggregation compounded with a circular movement, but is a simple right motion, never leaving

the line L E. But when thrown with an equal force from E toward F, and from E toward G, it completes an equal distance on either side, even though the daily rotation of the Earth is in process: just as twenty paces of a man mark an equal space whether toward East or West: so the Earth's diurnal motion is by no means refuted by the illustrious Tycho Brahe, through arguments such as these.



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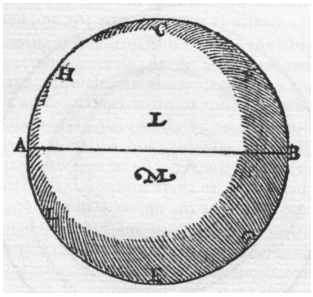

The tendency toward its origin (which, in the case of the Earth, is called by Philosophers weight) causes no resistance to the diurnal revolution, nor does it direct the Earth, nor does it retain the parts of the Earth in place, for in regard to the Earth's solidity they are imponderous, nor do they incline further, but are at rest in the mass. If there be a flaw in the mass, such as a deep cavity (say 1000 fathoms), a homogenic portion of the Earth, or compacted terrestrial matter, descends through that space (whether filled with water or air) toward an origin more assured than air or water, seeking a solid globe. But the centre of the Earth, as also the Earth as a whole, is imponderous; the separated parts tend toward their own origin, but that tendency we call weight; the parts united are at rest; and even if they were ponderable, they would introduce no hindrance to the diurnal revolution. For if around the axis A B, there be a weight at C, it is balanced from E; if at F, from G; if at H, from I. So internally at L, they are balanced from M: the whole globe, then, having a natural axis, is balanced in æquilibrio, and is easily set in motion by the slighted cause, but especially because the Earth in her own place is nowise heavy nor lacking in balance. Therefore weight neither hinders the diurnal revolution, nor influences either the direction or continuance in position. Wherefore it is manifest that no sufficiently strong reason has yet been found out by Philosophers against the motion of the Earth.

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CHAP. VI.

On the cause of the definite time, of an entire *rotation of the Earth.*

Diurnal motion is due to causes which have now to be sought, arising from magnetick vigour and from the confederated bodies; that is to say, why the diurnal rotation of the Earth is completed in the space of twenty-four hours. For no curious art, whether of Clepsydras or of sand-clocks, or those contrivances of little toothed wheels which are set in motion by weights, or by the force of a bent steel band, can discover any degree of difference in the time. But as soon as the diurnal rotation has been gone through, it at once begins over again. But we would take as the day the absolute turning of a meridian of the Earth, from sun to sun. This is somewhat greater than one whole revolution of it; in this way the yearly course is completed in 365 and nearly ¼ turnings with respect to the sun. From this sure and regular motion of the Earth, the number and time of 365 days, 5 hours, 55 minutes, in solar tropical years is always certain and definite, except that there are some slight differences due to other causes. The Earth therefore revolves not fortuitously, or by chance, or precipitately; but with a rather high intelligence, equably, and with a wondrous regularity, in no other way than all the rest of the movable stars, which have definite periods belonging to their motions. For the Sun himself being the agent and incitor of the universe in motion, other wandering globes set within the range of his forces, when acted on and stirred, also regulate each its own proper courses by its own forces; and they are turned about in periods corresponding to the extent of their greater rotation, and the differences of their effused forces, and their intelligence for higher good. And for that cause Saturn, having a wider orbit, is borne round it in a longer time, Jupiter a shorter, and Mars still less; while Venus takes nine months, Mercury 80 days, on the hypotheses of Copernicus; the Moon going round the Earth with respect to the Sun in 29 days, 12 hours, 44 minutes. We have asserted that the Earth moves circularly about its centre, completing a day by an entire revolution with respect to the Sun. The Moon revolves in a monthly course around the Earth, and, repeating a conjunction with the Sun after a former synodic conjunction, constitutes the month or Lunar day. The Moon's mean concentrick orbit, according to numerous observations of Copernicus and later astronomers, is found to be distant 29 and about 5/6 diameters of the Earth from the Earth's centre. The Moon's revolution with respect to the Sun takes place in 29½ days and 44 minutes of time. We reckon the motion with respect to the sun, not the periodic motion, just as a day is one entire revolution of the Earth with respect to the Sun, not one periodick revolution; because the Sun is the cause of lunar as of terrestrial motion: also, because (on the hypotheses of later observers) the synodical month is truly periodic, on account of the Earth's motion in a great orbit. The proportion of diameters to circumferences is the same. And the concentrick orbit of the Moon contains twice over 29 and ½ great circles of the Earth & a little more. The Moon & the Earth, then, agree together in a double proportion of motion; & the Earth moves in the space of twenty-four hours, in its diurnal motion; because the Moon has a motion proportional to the Earth, but the Earth a motion agreeing with the lunar motion in a

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nearly double proportion. There is some difference in details, because the distances of the stars in details have not been examined sufficiently exactly, nor are mathematicians as yet agreed about them. The Earth therefore revolves in a space of 24 hours, as the Moon in her monthly course, by a magnetick confederation of both stars, the globes being forwarded in their movement by the Sun, according to the proportion of their orbits, as Aristotle allows, *de Cœlo*, bk. ii., chap. 10. "It happens" (he says) "that the motions are performed through a proportion existing between them severally, namely, at the same intervals in which some are swifter, others slower," But it is more agreeable to the relation between the Moon and the Earth, that that harmony of motion should be due to the fact that they are bodies rather near together, and very like each other in nature and substance, and that the Moon has more evident effects upon the Earth than the rest of the stars, the Sun excepted; also because the Moon alone of all the planets conducts her revolutions, directly (however diverse even), with reference to the Earth's centre, and is especially akin to the Earth, and bound to it as with chains. This, then, is the true symmetry and harmony between the motions of the Earth and the Moon; not that old oft-besung harmony of cœlestial motions, which assumes that the nearer any sphære is to the *Primum Mobile* and that fictitious and pretended rapidest Prime Motion, the less does it offer resistance thereto, and the slower it is borne by its own motion from west to east: but that the more remote it is, the greater is its velocity, and the more freely does it complete its own movement; and therefore that the Moon (being at the greatest distance from the *Primum Mobile*) revolves the most swiftly. Those vain tales have been conceded in order that the *Primum Mobile* may be accepted, and be thought to have certain effects in retarding the motions of the lower heavens; as though the motion of the stars arose from retardation, and were not inherent and natural; and as though a furious force were perpetually driving the rest of the heaven (except only the *Primum Mobile*) with frenzied incitations. Much more likely is it that the stars are borne around symmetrically by their own forces, with a certain mutual concert and harmony.

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CHAP. VII.

On the primary magnetick nature of the Earth, whereby its poles are parted from the poles *of the Ecliptick.*

Primarily having shown the manner and causes of the diurnal revolution of the Earth, which is partly brought about from the vigour of the magnetick virtue, partly effected by the præ-eminence and light of the Sun; there now follows an account of the distance of its poles from the poles of the Ecliptick—a supremely necessary fact. For if the poles of the universe or of the Earth remained fast at the poles of the Zodiack, then the Æquator of the Earth would lie exactly beneath the line of the Ecliptick, and there would be no variation in the seasons of the year, no Winter, no Summer, nor Spring, nor Autumn: but one and the same invariable aspect of things would continue. The direction of the axis of the Earth has receded therefore from the pole of the Zodiack (for lasting good) just so far as is sufficient for the generation and variety of things. Accordingly the declination of the tropicks and the inclination of the Earth's pole remain perpetually in the twenty-fourth degree; though now only 23 degrees 28 minutes are counted; or, as others make out, 29 minutes: But once it was 23 degrees 52 minutes, which are the extreme limits of the declinations hitherto observed. And that has been prudently ordained by nature, and is arranged by the primary excellence of the Earth. For if those poles (of the Earth and the Ecliptick) were to be parted by a much greater distance, then when the Sun approached the tropick, all things in the other deserted part of the globe, in some higher latitude, would be desolate and (by reason of the too prolonged absence of the Sun) brought to destruction. As it is, however, all is so proportioned that the whole terrestrial globe has its own varying seasons in succession, and alternations of condition, appropriate and needful: either from the more direct and vertical radiation of light, or from its increased tarriance above the horizon.

Around these poles of the Ecliptick the direction of the poles of the Earth is borne: and by this motion the prækession of the æquinoxes is apparent to us.

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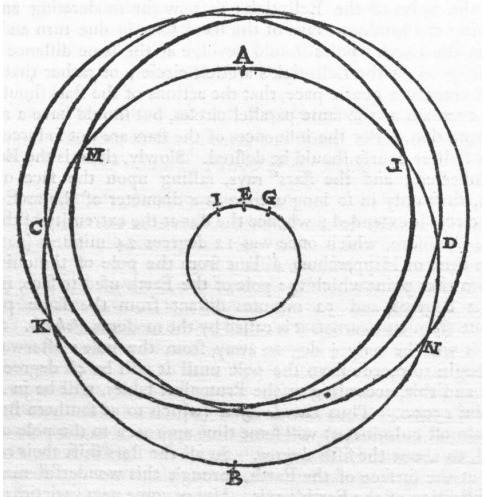
CHAP. VIII.

On the Prækession of the Æquinoxes, from the magnetick motion of the poles of the Earth, in the Arctick *and Antarctick circle of the Zodiack.*

Primitive mathematicians, since they did not pay attention to the inequælities of the years, made no distinction between the æquinoctial, or solstitial revolving year, and that which is taken from some one of the fixed stars. Even the Olympick years, which they used to reckon from the rising of the dogstar, they thought to be the same as those counted from the solstice. Hipparchus of Rhodes was the first to call attention to the fact that these differ from each other, and discovered that the year was longer when

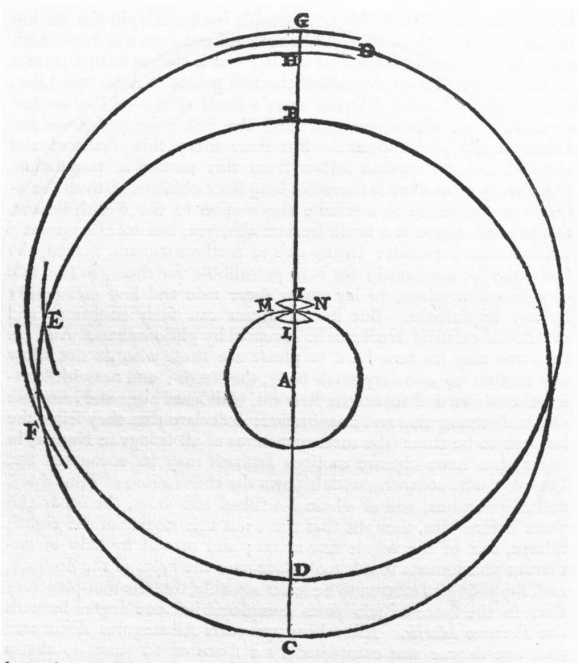
measured by the fixed stars than by the æquinox or solstice: whence he supposed that there was in the fixed stars also some motion in a common sequence; but very slow, and not at once perceptible. After him Menelaus, a Roman geometer, then Ptolemy, and long afterward Mahometes Aractensis, and several more, in all their literary memoirs, perceived that the fixed stars and the whole firmament proceeded in an orderly sequence, regarding as they did the heaven, not the earth, and not understanding the magnetical inclinations. But we shall demomstrate that it proceeds rather from a certain rotatory motion of the Earth's axis, than that that eighth sphære (so called) the firmament, or non-moving empyrean, revolves studded with innumerable globes and stars, whose distances from the Earth have never been proved by anyone, nor can be proved (the whole universe gliding, as it were). And surely it should seem much more likely that the appearances in the heavens should be clearly accounted for by a certain inflection and inclination of the comparatively small body of the Earth, than by the setting in motion of the whole system of the universe; especially if this motion is to be regarded as ordained solely for the Earth's advantage: While for the fixed stars, or for the planets, it is of no use at all. For this motion the rising and settings of stars in every Horizon, as well as their culminations at the height of the heavens, are shifted so much that the stars which once were vertical are now some degrees distant from the zenith. For nature has taken care, through the Earth's soul or magnetick vigour, that, just as it was needful in tempering, receiving, and warding off the sun's rays and light, by suitable seasons, that the points toward which the Earth's pole is directed should be 23 degrees and more from the poles of the Ecliptick[250]: so now for {235}
moderating and for receiving the luminous rays of the fixed stars in due turn and succession, the Earth's poles should revolve at the same distance from the Ecliptick at the Ecliptick's arctick circle; or rather that they should creep at a gentle pace, that the actions of the stars should not always remain at the same parallel circles, but should have a rather slow mutation. For the influences of the stars are not so forceful as that a swifter course should be desired. Slowly, then, is the Earth's axis inflected; and the stars' rays, falling upon the face of the Earth, shift only in so long a time as a diameter of the arctick or polar circle is extended: whence the star at the extremity of the tail of the Cynosure, which once was 12 degrees 24 minutes (namely, in the time of Hipparchus) distant from the pole of the universe, or from that point which the pole of the Earth used to face, is now only 2 degrees and 52 minutes distant from the same point; whence from its nearness it is called by the moderns *Polaris.* Some time it will be only ½ degree away from the pole: afterward it will begin to recede from the pole until it will be 48 degrees distant; and this, according to the Prutenical tables, will be in Anno Domini 15000. Thus *Lucida Lyræ* (which to us southern Britons now almost culminates) will some time approach to the pole of the world, to about the fifth degree. So all the stars shift their rays of light at the surface of the Earth, through this wonderful magnetical inflection of the Earth's axis. Hence come new varieties of the seasons of the year, and lands become more fruitful or more barren; hence the characters and manners of nations are changed; kingdoms and laws are altered, in accordance with the virtue of the fixed stars as they culminate, and the strength thence received or lost in accordance with the singular and specifick nature of each; or on account of new configurations with the planets in other places of the Zodiack; on account also of risings and settings, and of new concurrences at the meridian. The Præcession of the æquinoxes arising from the aequable motion of the Earth's pole in the arctick circle of the Zodiack is here demonstrated. Let A B C D be the Ecliptick line; I E G the arctic circle of the Zodiack. Then if the Earth's pole look to E, the æquinoxes are at D, C. Let this be at the time of Metho, when the horns of Aries were in the æquinoctial colure. Now if the Earth's pole have advanced to I; then the æquinoxes will be at K, L; and the stars in the ecliptick C will seem to have progressed, in the order of the signs, along the whole arc K C: L will be moved on by the præcession, against the order of the signs, along the arc D L. But this would occur in the contrary order, if the point G were to face the poles of the earth, and the motion were from E to G: for then the æquinoxes would be M N, and the fixed stars would anticipate the same at C and D, counter to the order of the signs.



CHAP. IX. {236}

On the anomaly of the Præcession of the Equinoxes, *and of the obliquity of the Zodiack.*

At one time the shifting of the æquinoxes is quicker, at another slower, being not always equal: because the poles of the earth travel unequally in the arctick and antarctick circle of the Zodiack; and decline on both sides from the middle path: whence the obliquity of the Zodiack to the Æquator seems to change. And as this has become known by means of long observations, so also has it been perceived, that the true æquinoctial points have been elongated from the mean æquinoctial points, on this side and on that, by 70 minutes (when the prostaphæresis is greatest): but that the solstices either approach the equator unequally 12 minutes nearer, or recede as far behind; so that the nearest approach is 23 degrees 28 minutes, and the greatest elongation 23 degrees 52 minutes. Astronomers have given various explanations to account for this inequality of the præcession and also of the obliquity of the tropicks. Thebit, with the view of laying down a rule for such {237} considerable inequalities in the motion of the stars, explained that the eighth sphære does not move with a continuous motion from west to east; but is shaken with a certain motion of trepidation, by which the first points of Aries and Libra in the eighth heaven describe certain small circles with diameters equal to about nine degrees, around the first points of Aries and Libra in the ninth sphære. But since many things absurd and impossible as to motion follow from this motion of trepidation, that theory of motion is therefore long since obsolete. Others therefore are compelled to attribute the motion to the eighth sphære, and to erect above it a ninth heaven also, yea, and to pile up yet a tenth and an eleventh: In the case of mathematicians, indeed, the fault may be condoned; for it is permissible for them, in the case of difficult motions, to lay down some rule and law of equality by any hypotheses. But by no means can such enormous and monstrous celestial structures be accepted by philosophers. And yet here one may see how hard to please are those who do not allow any motion to one very small body, the Earth; and notwithstanding they drive and rotate the heavens, which are huge and immense above all conception and imagination: I declare that they feign the heavens to be three (the most monstrous of all things in Nature) in order that some obscure motions forsooth[251] may be accounted for. Ptolemy, who compares with his own the observations of Timocharis and Hipparchus, one of whom flourished 260 years, the other 460 years before him, thought that there was this motion of the eighth sphære, and of the whole firmament; and proved by help of numerous phenomena that it took place over the poles of the Zodiack, and, supposing its motion to be so far æquable, that the non-planetary stars in the space of 100 years completed just one degree beneath the *Primum Mobile*. After him 750 years Albategnius discovered that one degree was completed in a space of 66 years, so that a whole period would be 23,760 years. Alphonsus made out that this motion was still slower, completing one degree and 28 minutes only in 200 years; and that thus the course of the fixed stars went on, though unequally. At length Copernicus, by means of the observations of Timocharis, Aristarchus of Samos, Hipparchus, Menelaus, Ptolemy, Mahometes Aractensis, Alphonsus, and of his own, detected the anomalies of the motion of the Earth's axis: though I doubt not that other anomalies also will come to light some ages hence. So difficult is it to observe motion so slow, unless extending over a period of many centuries; on which account we still fail to understand the intent of Nature, what she is driving after through such inequality of motion. Let A be the pole of the Ecliptick, B C the Ecliptick, D the Æquator; when the pole of the Earth near the arctick circle of the Zodiack faces the point M, then there is an anomaly of the præcession of the æquinox at F; but when it faces N, {238} there is an anomaly of the præcession at E. But when it faces I directly, then the maximum obliquity G is observed at the solstitial colure; but when it faces L, there is the minimum obliquity H at the solstitial colure.



Copernicus' contorted circlet in the Arctick circle of the Zodiack.

Let F B G be the half of the Arctick circle described round the pole of the Zodiack: A B C the solstitial colure: A the pole of the Zodiack; D E the anomaly of longitude 140 minutes at either side on both ends: B C the anomaly of obliquity 24 minutes: B the greater obliquity of 23 degrees 52 minutes: D the mean obliquity of 23 degrees 40 minutes: C the minimum obliquity of 23 degrees 28 minutes.

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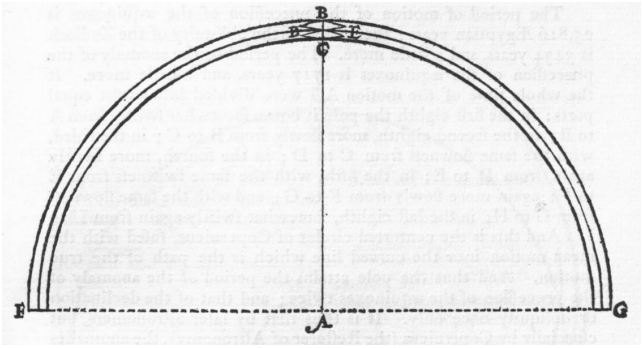

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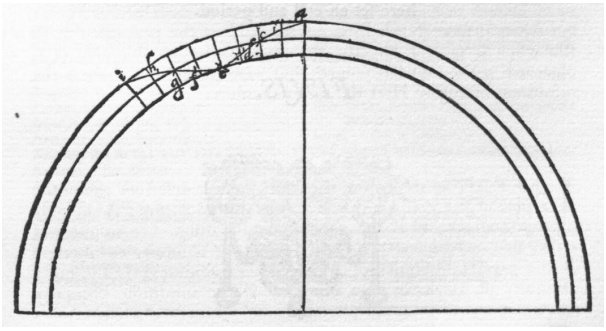

The period of motion of the præcession of the æquinoxes is 25,816 Ægyptian years; the period of the obliquity of the Zodiack is 3434 years, and a little more. The period of the anomaly of the præcession of the æquinoxes is 1717 years, and a little more. If the whole time of the motion AI were divided into eight equal parts: in the first eighth the pole is borne somewhat swiftly from A to B; in the second eighth, more slowly from B to C; in the third, with the same slowness from C to D; in the fourth, more swiftly again from D to E; in the fifth, with the same swiftness from E to F; again more slowly from F to G; and with the same slowness from G to H; in the last eighth, somewhat swiftly again from H to I. And this is the contorted circlet of Copernicus, fused with the mean motion into the curved line which is the path of the true motion. And thus the pole attains the period of the anomaly of the præcession of the æquinoxes twice; and that of the declination or obliquity once only. It is thus that by later astronomers, but especially by Copernicus (the Restorer of Astronomy)[252], the anomalies of the motion of the Earth's axis are described, so far as the observations of the ancients down to our own times admit; but there are still needed more and exact observations for anyone to establish aught certain about the anomaly of the motion of the præcessions, and at the same time that also of the obliquity of the Zodiack. For ever since the time at which, by means of various observations, this anomaly was first observed, we have only arrived at half a period of the obliquity. So that all the more all these matters about the unequal motion both of the præcession and of the obliquity are uncertain and not well known: wherefore neither can we ourselves assign any natural causes for it, and establish it for certain. Wherefore also do we to our reasonings and experiments magnetical here set an end and period.[253]

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INDEX.

THIS TREATISE BY WILLIAM GILBERT, OF COLCHESTER, PHYSICIAN OF LONDON, ON THE MAGNET, WAS FIRST PUBLISHT IN THE LATIN TONGUE IN LONDON IN THE YEAR OF OUR LORD M.D.C.; THIS ENGLISH TRANSLATION, WHICH WAS COMPLETED IN THE YEAR M.C.M., IS PRINTED FOR THE GILBERT CLUB, TO THE NUMBER OF TWO HUNDRED AND FIFTY COPIES, BY CHARLES WHITTINGHAM AND COMPANY, AT THE CHISWICK PRESS, TOOKS COURT, CHANCERY LANE, LONDON. {247}

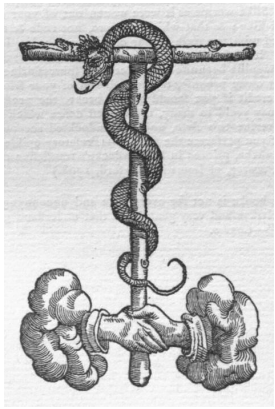
NOTES

ON THE

DE MAGNETE

OF

DR. WILLIAM GILBERT



PRIVATELY PRINTED

LONDON MCMI

"For out of olde feldes, as men seith,
Cometh al this newe corn fro yeer to yere;
And out of olde bokes, in good feith,
Cometh al this newe science that men lere."
—*Chaucer.*

"I finde that you have vsed in this your trāslation greate art, knowledge, and discretion. For walking as it were in golden fetters (as al Translators doe) you notwithstanding so warilie follow your Auctor, that where he trippeth you hold him vp, and where he goeth out of the way, you better direct his foote. You haue not only with the Bee sucked out the best iuyce from so sweete a flower, but with the Silke-worme as it were wouen out of your owne bowels, the finest silke; & that which is more, not rude & raw silke, but finely died with the fresh colour of your owne Art, Invention, and Practise. If these Adamantes draw you not to effect this which you haue so happilie begunne: then let these spurres driue you forward: viz. Your owne promise, the expectation of your friends, the losse of some credit if you should steppe backe, the profit which your labours may yeeld to many, the earnest desire which you yourselfe haue to reviue this Arte, and the vndoubted acceptation of your paines, if you performe the same."—(Prefatory epistle of John Case, D. of Physicke, printed in R. Haydocke's translation of *The Artes of Curious Painting*, of Lomatius, Oxford, 1598.)

"This booke is not for every rude and unconnynge man to see, but for clerkys and very gentylmen that understand gentylness and scyence."—*Caxton.*

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BIBLIOGRAPHY OF *DE MAGNETE*.

I. **(The London Folio of 1600.)** *Fol. *j. title* GVILIELMI GIL | berti colcestren | sis, medici londi- | nensis, | DE MAGNETE, MAGNETI- | cisqve corporibvs, et de mag- | no magnete tellure; Physiologia noua, | plurimis & argumentis, & expe- | rimentis demonstrata. | *Printer's Mark* | Londini | excudebat Petrvs Short anno | MDC. || **j verso* Gilbert's coat of arms. || **ij* Ad Lectorem || **iij verso* Ad gravissimvm doctissimvmqve ... || **vj* Verborum quorundam interpretatio. || **vj verso* Index capitum. || p. 1. GVILIELMI GILBERTI | DE MAGNETE, LIB. I. || p. 240. FINIS. | Errata. Without any colophon, printer's Mark, or date at end. *Folio. 8 ll. of preliminary matter.* ABCDEFGHIKLMNOPQRSTV, *all ternions, making 120 numbered leaves. One blank leaf at front and one at end. Page 114 at end of Liber II. blank. A folded woodcut plate inserted between p. 200 and p. 201. Woodcut initials, headlines and diagrams. All known copies except one have ink corrections in several pages, particularly pp. 11, 22, 47.*

II. **(The Stettin Quarto of 1628.)** *Four preliminary unnumbered leaves, viz.* (1) *Bastard title* GULIELMI GILBERTI | Tractatus | DE MAGNETE || *verso* blank; (2) *Engraved title.* TRACTATVS | Siue | PHYSIOLOGIA NOVA | DE MAGNETE, | MAGNETICISQVE CORPO- | RIBVS ET MAGNO MAGNETE | tellure Sex libris comprehensus | ã | Guilielmo Gilberto Colcestrensi, | Medico Londinensi | ... Omnia nunc diligenter recognita & emen- | datius quam ante in lucem edita, aucta & figu- | ris illustrata operâ & studio | Wolfgangi **Lochmans** I.U.D. | & Mathemati: | Ad calcem libri adjunctus est Index Capi- | tum Rerum et Verborum locupletissimus | EXCVSVS SEDINI | Typis Gotzianis Sumptibus | *Ioh: Hallervordij.* | Anno MDC.XXVIII || *verso* blank; (3) Præfatio; (4) Amicorum Acclamationes (verses) || *verso* blank. *Sig.* A Ad Lectorem Candidum. *Sig.* A2 *verso* Ad Gravissimum Doctissimumq̄ Virum. *Sig.* B2 Verborum quorundam interpretatio. *Verso* blank, followed by twelve engraved plates numbered I. to XII. *Sig.* B3 is numbered as p. 1, and begins GVILIELMI GILBERTI | DE MAGNETE. | LIBER I. *Sig.* C *begins as p. 5*; *Sig.* D as p. 13; and so forth. The collation therefore is: 4 ll. unnumbered, ABCDEFGHIKLMNOPQRSTVXYZAaBbCcDdEeFfGgHhIiKkLlMm, *all fours. Pagination ends on* p. 232, *which has Sig.* H_3 *in error for* Hh_3, *being the end of the text. Verso of* Hh_3 blank. Index capitum *begins fol.* [Hh_4] *and* with Index Verborum *continues to verso of* Mm_3. *Last leaf* [Mm_4] *contains Errata, and instructions to binder to place plates: verso* blank. *Quarto. Woodcut initials and diagrams. Without any colophon, printer's Mark, or date at end.* In some copies the engraved title differs, having the words *Ioh: Hallervordij.* replaced by the word *Authoris*.

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III. **(The Stettin Quarto of 1633.)** *Four preliminary unnumbered leaves*, viz., (1) *title.* Tractatus, sive Physiologia Nova | de | MAGNETE, | Magneticisq; corporibus & magno | Magnate tellure, sex libris comprehensus, | a GUILIELMO GILBERTO Colce- | strensi, Medico Londinensi. | ... Omnia nunc diligenter recognita, & emendatius quam ante | in lucem edita, aucta & figuris illustrata, opera & studio D. | WOLFGANGI LOCHMANS, I.U.D. | & Mathematici. | Ad calcem libri adiunctus est Index capitum, Rerum & Verborum | locupletissimus, qui in priore æditione desiderabatur | SEDINI, | Typis GOTZIANIS. | ANNO M.DC. XXXII. || *verso* blank; (2) Præfatio; (3) Amicorum acclamationes (verses) || *verso* Claudianus de Magnete (verses); (4) *ibid. Sig.* A Ad Lectorem Candidum. *Sig.* A2 *verso* Ad Gravissimum Doctissimumq. Virum. *Sig.* B2 Verborum

quorundam interpretatio; *verso* blank. *Sig.* B3 is numbered as p. 1, and begins GVILIELMI GILBERTI | DE MAGNETE. | LIBER I. *Sig.* C begins as p. 5; *Sig.* D as p. 13; and so forth. The Collation therefore is: 4 *ll.* unnumbered, A *to* Mm, *all fours*. Pagination *ends on p. 232, which bears Sig.* H3 *in error for* Hh3. *Verso of Sig.* Hh3. Errata. Index capitum *begins* Hh4, *and with* Index Verborum *extends to verso* of Mm3. *The last leaf* [Mm4] *bears the Instructions to binder, with verso* blank. *There is no colophon, printer's Mark, or date at end. Quarto. Woodcut initials, and diagrams. Twelve etched plates of various sizes inserted.*

With the exception of the preliminary matter and the Instructions to binder, the pagination is the same as in the edition of 1628, the pages in the body of the work being reprinted word for word; though with exceptions. For example, p. 18 in Ed. 1633 is one line shorter than in Ed. 1628. The etched plates are entirely different. It has been thought from the pagination being alike that these two editions were really the same with different plates, titles, and preliminary matter. But they are really different. The spacing of the words, letters and lines is different throughout, and there are different misprints. The watermarks of the paper also differ.

IV. (**The Berlin "facsimile" Folio of 1892.**) This is a photozincograph reproduction of the London folio of 1600. It lacks the ink emendations on pages 11, 22, 47, &c., found in the original, and is wanting also in some of the asterisks in the margins.

V. (**The American translation of 1893.**) Frontispiece portrait || *p. i. title* WILLIAM GILBERT | OF COLCHESTER, | physician of London, | on the | Loadstone and Magnetic Bodies, | and on | the great magnet the earth. | A new Physiology, | demonstrated with many arguments and experiments. | A translation by | P. Fleury Mottelay, | ... | New York: | John Wiley & Sons, | 53 East Tenth Street | 1893. || *p. ii* bears imprint of Ferris Bros. *Printers*, 326 Pearl Street, New York. || *p. iii.* reduced reproduction of title of 1600 edition || *verso* the Gilbert arms || *p. v.* Translator's Preface || *p. ix.* Biographical Memoir || *p. xxxi.* Contents || *p. xxxvii.* Address of Edward Wright || *p. xlvii.* Author's Preface. || *p. liii.* Explanation of some terms. || pp. 1-358 text of the work. || p. 359 reduced reproduction of title of 1628 edition. || p. 360 *ditto* of 1633 edition. || p. 361 *ditto* of Gilbert's *De Mundo Nostro* of 1651. || pp. 363 to 368 General Index. || Pages *xxx*, *xlvi*, *lii*, and 362 are blanks. There are no signatures. Octavo. Diagrams reduced from woodcuts of the folio of 1600. Some copies bear on title the imprint | London: | Bernard Quaritch, | 15 Piccadilly. ||

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NOTES ON THE *DE MAGNETE* OF DR. WILLIAM GILBERT.

During the work of revising and editing the English translation of *De Magnete*, many points came up for discussion, requiring critical consideration, and the examination of the writings of contemporary or earlier authorities. Discrepancies between the texts of the three known editions —the London folio of 1600, and the two Stettin quartos of 1628 and 1633 respectively— demanded investigation. Passages relating to astrology, to pharmacy, to alchemy, to geography, and to navigation, required to be referred to persons acquainted with the early literature of those branches. Phrases of non-classical Latin, presenting some obscurity, needed explanation by scholars of mediæval writings. Descriptions of magnetical experiments needed to be interpreted by persons whose knowledge of magnetism enabled them to infer the correct meaning to be assigned to the words in the text. In this wise a large amount of miscellaneous criticism has been brought to bear, and forms the basis for the following notes. To make them available to all students of Gilbert, the references are given to page and line both of the Latin folio of 1600 and of the English edition of 1900. S. P. T.

[1] *THE GLOSSARY:*

Gilbert's glossary is practically an apology for the introduction into the Latin language of certain new words, such as the nouns *terrella*, *versorium*, and *verticitas*, and the adjectival noun *magneticum*, which either did not exist in classical Latin or had not the technical meaning which he now assigns to them. His *terrella*, or μικρόγη, as he explains in detail on p. 13, is a little magnetic model of the earth, but in the glossary he simply defines it as *magnes globosus*. Neither *terrella* nor *versorium* appears in any Latin dictionary. No older writer had used either word, though Peter Peregrinus (*De Magnete*, Augsburg, 1558) had described experiments with globular loadstones, and pivotted magnetic needles suitable for use in a compass had been known for nearly three centuries. Yet the pivotted needle was not denominated *versorium*. Blondo (*De Ventis*, Venice, 1546) does not use the term. Norman (*The Newe Attractiue*, London, 1581) speaks of the "needle or compasse," and of the "wyre." Barlowe (*The Navigators Supply*, London, 1597) speaks of the "flie," or the "wier." The term *versorium* (literally, the *turn-*

{2}

about) is Gilbert's own invention. It was at once adopted into the science, and appears in the treatises of Cabeus, *Philosophia Magnetica* (Ferrara, 1629), and of Kircher, *Magnes sive de Arte Magnetica* (Coloniæ, 1643), and other writers of the seventeenth century. Curiously enough, its adoption to denote the pivotted magnetic needle led to the growth of an erroneous suggestion that the mariners' compass was known to the ancients because of the occurrence in the writings of Plautus of the term *versoriam*, or *vorsoriam*. This appears twice as the accusative case of a feminine noun *versoria*, or *vorsoria*, which was used to denote part of the gear of a ship used in tacking-about. Forcellini defines *versoria* as "funiculus quo extremus veli angulus religatur"; while *versoriam capere* is equivalent to "reverti," or (metaphorically) "sententiam mutare." The two passages in Plautus are:

> Eut. Si huc item properes, ut istuc properas, facias rectius,
> Huc secundus ventus nunc est; cape modo vorsoriam;
> Hic Favonius serenu'st, istic Auster imbricus:
> Hic facit tranquillitatem, iste omnes fluctus conciet.
> (in *Mercat.* Act. V., sc. 2.)

> Charm. Stasime, fac te propere celerem recipe te ad dominum domum;
> . . . . . .
> . . . . . .
> . . . . . Cape vorsoriam
> Recipe te ad herum.
> (in *Trinum.* Act. IV., sc. 3.)

The word *magneticum* is also of Gilbert's own coinage, as a noun; as an adjective it had been certainly used before, at least in its English form, *magneticall*, which appears on the title-page of William Borough's *Discourse of the Variation of the Compasse* (London, 1596). Gilbert does not use anywhere the noun *magnetismus*, *magnetism*. The first use of that noun occurs in William Barlowe's *Magneticall Aduertisements* (1616), in the *Epistle Dedicatorie*, wherein, when speaking of Dr. Gilbert, he says "vnto whom I communicated what I had obserued of my selfe, and what I had built vpon his foundation of the *Magnetisme* of the earth." Gilbert speaks of the *virtus magnetica*, or *vis magnetica*; indeed, he has a rich vocabulary of terms, using, beside *virtus* and *vis*, *vires*, *robur*, *potestas*, *potentia*, *efficientia*, and *vigor* for that which we should now call *magnetism* or *the magnetic forces*. Nor does he use the verb *magnetisare*, or its participle, *magnetisatus*: he speaks of *ferrum tactum*, or of *ferrum excitatum a magnete*. In spite of certain obscurities which occur in places in his work, he certainly shows a nice appreciation of words and their use, and a knowledge of style. One finds occasionally direct quotations from, and overt references to, the classic authors, as in the references to Plato and Aristotle on page 1, and in the passage from the Georgics of Vergil on p. 21. But here and there one finds other traces of unmistakable scholarship, as in the reference to goat's wool on p. 35, or in the use, on p. 210, of the word *perplacet*, which occurs in the letter of Cicero *ad Atticum*, or in that of *commonstrabit*, occurring on p. 203, and found only in Cicero, Terence and Plautus; whilst the phrase on p. 3, in which Gilbert rallies the smatterers on having lost both their oil and their pains, has a delightfully classical echo. The term *orbis virtutis*, defined by Gilbert in the glossary, and illustrated by the cuts on pages 76, 77, and 96, might be effectively translated by *sphere of influence*, or *orbit within which there is sensible attraction*. It has been preferred, however, to translate it literally as the *orbe of virtue*, or *orbe of magnetick virtue*. This choice has been determined by the desire to adopt such an English phrase as Gilbert would himself have used had he been writing English. T. Hood, writing in 1592 in his book *The Vse of both the Globes*, in using the word *orbe*, says that the word *globe* signifies a solid body, while a *sphere* is hollow, like two "dishes joyned by the brimme"; "The Latines properly call *Orbis* an Orbe"; "Moreouer the word *Sphaera* signifieth that instrument made of brasen hoopes (wee call it commonly a ringed Sphere) wherewith the Astronomers deliuer unto the nouices of that Science the vnderstanding of things which they imagine in the heauen." Further, Dr. Marke Ridley in his *Treatise of Magneticall Bodies and Motions* (1613), has a chapter (XIIII) "Of the distance and Orbe of the Magnets vertue," throughout which the term Orbe is retained. Sir Thomas Browne also writes of "the orb of their activities." {3}

The word *Coitio*, used by Gilbert for the mutual force between magnet and iron, has been retained in its English form, *coition*. Gilbert evidently adopted this term after much thought. The Newtonian conception of action and reaction being necessarily equal had not dawned upon the mediæval philosophers. The term *attraction* had been used in a limited sense to connote an action in which a force was conceived of as being exerted on one side only. Diogenes of Apollonia, Alexander Aphrodiseus, Democritus, and others, conceived the magnet to draw at the iron without the iron in any way contributing to that action. Saint Basil specially affirms that the magnet is not drawn by iron. On the other hand, Albertus Magnus had conceived the idea that the iron sought the magnet by a one-sided effort in which the magnet took no part. Gilbert had the wit to discern that the action was mutual, and to mark the new conception he adopted the new term, and defined it as it stands in his glossary. It is "a concourse or concordancy of both," and to emphasize his meaning he adds, "not as if there were an ἑλκτικὴ δύναμις but a συνδρομή"

not a tractile power, but a running together. The adjective ἑλκτικὴ is obviously related to the verb ἕλκω, I draw: but its meaning puzzled the subsequent editors of the text, for in the two Stettin editions of 1628 and 1633, the phrase appears in the respective forms of ἑλητικὴ δύναμις and ἑλκυστικὴ δύναμις. In Creech's English version of Lucretius (edition of 1722, p. 72a, in the footnote) is the commentary "Galen, disputing against Epicurus, uses the term ἑλκεῖν, which seems likewise too violent." It may be noted that the same verb occurs in the passage from the *Io* of Plato quoted below. The term συνδρομή applied by Gilbert to explain his term *Coitio* is used by Diodorus for the mutual onset of two hostile forces.

A picturesque sentence from Sir Thomas Browne's *Pseudodoxia Epidemica* (London, 1650, p. 51) sets the matter succinctly forth. "If in two skiffs of cork, a Loadstone and Steel be placed within the orb of their activities, the one doth not move the other standing still, but both hoist sayle and steer unto each other; so that if the Loadstone attract, the Steel hath also its attraction; for in this action the Alliency is reciprocall, which jointly felt, they mutually approach and run into each others arms." The page and {4}
line references given in these notes are in all cases first to the Latin edition of 1600, and secondly to the English edition of 1900.

[2] **Page 1, line 28.** Page 1, line 28. *Plato in Ione.*—The passage in the *Io* of Plato is in chap. v. Socrates addressing the poet Io tells him that his facility in reciting Homer is not really an art: θεία δὲ δύναμις, ἥ σε κινεῖ ὥσπερ ἐν τῇ λίθῳ, ἣν Εὐριπίδης μὲν Μαγνῆτιν ὠνόμασεν, οἱ δὲ πολλοὶ Ἡράκλειαν. καὶ γὰρ ἅυτη ἡ λίθος οὐ μόνον αὐτοὺς τοὺς δακτυλίους ἄγει τοὺς σιδηροῦς, ἀλλὰ καὶ δύναμιν ἐντίθησι τοῖς δακτυλίοις, ὥστ ἄυ δύνασθαι ταυτὸυ τοῦτο ποιεῖν, ὅπερ ἡ λίθος, ἄλλους ἄγειν δακτυλίους, ὥστ' ἐνίοθ' ὁρμαθὸς μακρὸς πάνυ σιδηρίων καὶ δακτυλίων ἐξ ἀλλήλων ἤρτηται πᾶσι δὲ τούτοις ἐξ ἐκείνης τῆς λίθου ἡ δύναμις ἀνήρτηται. The idea is that as the loadstone in attracting an iron ring will make it into a magnet, which can in turn act magnetically on another ring, and this on yet another, so the inspiration of the Muse is transferred to the poet, who in turn hands on the inspiration through the reciter to the listener. After further expanding the same idea of the transference of influence, Socrates again mentions the magnet (chap. vii.): Ὅισθ' ὅυν ὅτι οὐτός ἐστιν ὁ θεατὴς τῶν δακτυλίων ὁ ἔσχατος, ὧν ἐγὼ ἔλεγον ὑπὸ τῆς Ἡρακλειώτιδος λίθου ἀπ' ἀλλήλων τὴν δύναμιν λαμβάνειν, ὁ δὲ μέσος σὺ ὁ ῥαψωδὸς καὶ ὑποκριτής, ὁ δὲ πρῶτος αὐτὸς ὁ ποιητής; ὁ δὲ θεὸς διὰ πάντων τούτων ἕλκει τὴν ψυχὴν ὅποι ἂν βούληται τῶν ἀνθρώπων, κ.τ.λ. (Edition Didot of 1856, vol. i., p. 391; or Stephanus, p. 533 D).

There is another reference in Plato to the magnet, namely, in the *Timæus* (p. 240, vol. ii., Edit. citat.). See the Note to p. **61**.

The reference by Euripides to the magnet occurs in the lost play of Œneus, in a fragment preserved by Suidas. See *Fragmenta Euripidis* (Ed. Didot, 1846, p. 757, or Nauck's edition, No. 567).

ὡς Εὐριπίδης ἐν Οἰνεῖ· τὰς βροτῶν γνώμας σκοπῶν, ὥστε Μαγνῆτις λίθος τὴν δόξαν ἕλκει καὶ μεθίστησιν πάλιν.

[3] **Page 1, line 28.** Page 1, line 29. The brief passage from Aristotle's *De Anima* referring to Thales is quoted by Gilbert himself at the bottom of p. **11**.

[4] **Page 2, line 1.** Page 1, line 29. The edition of 1628 inserts commas between Theophrastus and Lesbius, and between Julius and Solinus, as though these were four persons instead of two.

[5] **Page 2, line 8.** Page 2, line 5. *si allio magnes illitus fuerit, aut si adamas fuerit*. An excellent version of this myth is to be found in Julius Solinus, *Polyhistor, De Memorabilibus*, chap. lxiv., of which the English version of 1587, by A. Golding, runs thus: "The Diamonde will not suffer the Lodestone to drawe yron unto him: or if y^{e} Lodestone haue alreadie drawne a peece of yron to it, the Diamond snatcheth and pulleth away as hys bootye whatsoever the Lodestone hath taken hold of." Saint Augustine repeats the diamond myth in his *De Civitate Dei*, lib. xxi. Baptista Porta says (p. 211 of the English version of 1658): "It is a common Opinion amongst Sea-men, That Onyons and Garlick are at odds with the Loadstone: and Steers-men, and such as tend the Mariners Card are forbid to eat Onyons or Garlick, lest they make the Index of the Poles drunk. But when I tried all these things, found them to be false: for not onely breathing and belching upon the Loadstone after eating of Garlick, did not stop its vertues: but when it was all anoynted over with the juice of Garlick, 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, lest I should make void the endeavours of the Ancients. And again, When I enquired of Marines, {5}
whether it were so, that they were forbid to eat Onyons and Garlick for that reason; they said, they were old Wives fables, and things ridiculous; and that Sea-men would sooner lose their lives, then abstain from eating Onyons and Garlick."

The fables respecting the antipathy of garlick and of the diamond to the operation of the magnet, although already discredited by Ruellius and by Porta, died hard. In spite of the exposure and denunciations of Gilbert—compare p. **32**—these tales were oft repeated during the succeeding century. In the appendix to Sir Hugh Plat's *Jewel House of Art and*

Nature, in the edition of 1653, by D. B. Gent, it is stated there (p. 218): "The Loadstone which ... hath an admirable vertue not onely to draw Iron to it self, but also to make any Iron upon which it is rubbed to draw iron also, it is written notwithstanding, that being rubbed with the juyce of Garlick, it loseth that vertue, and cannot then draw iron, as likewise if a Diamond be layed close unto it."

Pliny wrote of the alleged antipathy between diamond and goat's blood. The passage as quoted from the English version of Pliny's *Natural Historie of the World*, translated by Philemon Holland (London, 1601, p. 610, chap, iv.), runs: "But I would gladly know whose invention this might be to soake the Diamond in Goats bloud, whose head devised it first, or rather by what chance was it found out and knowne? What conjecture should lead a man to make an experiment of such a singular and admirable secret, especially in a goat, the filthiest beast ... in the whole world? Certes I must ascribe both this invention and all such like to the might and beneficence together of the divine powers: neither are we to argue and reason how and why Nature hath done this or that? Sufficient is it that her will was so, and thus she would have it."

[6] **Page 2, line 22.** Page 2, line 22. *Machometis sacellum.* Gilbert credits Matthiolus (the well-known herbalist and commentator on Dioscorides) with producing the fable as to Mahomet's coffin being suspended in the air by a magnet. Sir Richard Burton, in his famous pilgrimage to El Medïnah in 1855, effectually disposed of this myth. The reputed sarcophagus rests simply on bricks on the floor. But it had long been known that aerial suspension, even of the lightest iron object, in the air, without contact above or below, was impossible by any magnetic agency.

In Barlowe's *Magneticall Aduertisements* (London, 1616, p. 45) is the following: "As for the Turkes *Mahomet*, hanging in the ayer with his yron chest it is a most grosse untruth, and utterly impossible it is for any thing to hange in the ayer by any *magneticall* power, but that either it must touch the stone it selfe, or else some intermediate body, that hindreth it from comming to the stone (like as before I haue shewed) or else some stay below to keepe it from ascending, as some small wier that may scantly bee seene or perceived."

[7] **Page 2, line 26.** Page 2, line 26. *Arsinoes templum.*—The account in Pliny of the magnetic suspension of the statue of Arsinoe in the temple built by Chinocrates is given as follows in the English version (London, 1601) of Philemon Holland (p. 515): "And here I cannot chuse but acquaint you with the singular invention of that great architect and master deviser, of Alexandria in Ægypt *Dinocrates*, who began to make the arched roufe 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 yron, might seeme to hang in the aire by nothing. But prevented he was by death before hee could finish his worke, like as king *Ptolomæe* also, who ordained that temple to be built in the honour of the said *Arsinoe* his sister." {6}

There are a number of similar myths in Ausonius, Claudian, and Cassiodorus, and in the writings of later ecclesiastical historians, such as Rusinus and Prosper Aquitanus. The very meagre accounts they have left, and the scattered references to the reputed magical powers of the loadstone, suggest that there existed amongst the primitive religions of mankind a *magnet-worship*, of which these records are traces.

[8] **Page 2, line 37.** Page 2, line 41. *Brasevolus* [or *Brasavola*].—The list of authorities here cited consists mostly of well-known mediæval writers on *materia medica* or on minerals: the last on the list, *Hannibal Rosetius Calaber*, has not been identified.

The following are the references in the order named by Gilbert:

Antonio Musa Brasavola. *Examen omnium simplicium medicamentorum*, Section 447 (Lugdun., 1537).

Joannes Baptista Montanus. *Metaphrasis summaria eorum quæ ad medicamentorum doctrinà attinet* (Augustæ Rheticæ, 1551).

Amatus Lusitanus. *Amati Lusitani in Dioscoridis Anazarbei de materia medica libros quinque* (Venet., 1557, p. 507).

Oribasius. *Oribasii Sardiani ad Eunapium libri 4 quibus ... facultates simplicium ... continentur* (Venet., 1558).

Aetius Amidenus. *Aetii Amideni Librorum medicinalium ... libri octo nunc primum in lucem editi* (Greek text, Aldine edition, Venet., 1534). A Latin edition appeared in Basel, 1535. See also his *tetrabiblos ex veteribus medicinæ* (Basil., 1542).

Avicenna (Ibn Sinâ). *Canona Medicinæ* (Venice, 1486), liber ii., cap. 474.

Serapio Mauritanus (Yuhanná Ibn Sarapion). In hoc volumine continentur ... *Ioan. Sarapionis Arabis de Simplicibus Medicinis opus præclarum et ingens ...* (edited by Brunfels, Argentorati, 1531, p. 260).

Hali Abbas (’Alí Ibn Al ’Abbās). *Liber totius medicinæ necessaria cõtinens ... quem Haly filius Abbas edidit ... et a Stephano ex arabica lingua reductus* (Lugd., 1523, p. 176

verso).

Santes de Ardoniis (or Ardoynis). *Incipit liber de venenis quem magister santes de ardoynis ... edere cepit venetiis die octauo nouẽbris*, 1424 (Venet., 1492).

Petrus Apponensis (or Petrus de Abano). The loadstone is referred to in two works by this author.

(1) *Conciliator differentiarum philosophorum: et precipue medicorum clarissimi viri Petri de Abano Patauini feliciter incipit* (Venet., 1496, p. 72, *verso*, Quæstio LI.).

(2) *Tractatus de Venenis* (Roma, 1490, cap. xi.).

Marcellus (called Marcellus Empiricus). *De Medicamentis*, in the volume *Medici antiqui omnes* (Venet., 1547, p. 89).

Arnaldus (Arnaldus de Villa Nova). *Incipit Tractatus de virtutibus herbarum* (Venet., 1499). See also *Arnaldi Villanovani Opera omnia* (Basil., 1585).

Marbodeus Gallus. *Marbodei Galli poetae vetustissimi de lapidibus pretiosis Enchiridion* (Friburgi, 1530 [1531], p. 41).

Albertus Magnus. *De Mineralibus et rebus metallicis* (Venet., 1542, lib. ii., *de lapidibus preciosis*, p. 192). There is a reference to the loadstone also in a work attributed falsely {7}
to Albertus, but now ascribed to Henricus de Saxonia, *De virtutibus herbarum, de virtutibus lapidum*, etc. (Rouen, 1500, and subsequent editions). An English version, *The Secrets of Albertus Magnus of the vertues of hearbs stones and certaine beasts* was publisht in London in 1617.

Matthæus Silvaticus. *Pandectæ Medicinæ* (Lugduni, 1541, cap. 446).

Hermolaus Barbarus. His work, *Hermolai Barbari Patritii Veneti et Aqvileiensis patriarchæ Corollarii Libri quinque ...* Venet., 1516, is an early herbal. On p. 103 are to be found descriptions of *lapis gagatis* and *lapis magnes*. The latter is mostly taken from Pliny, and mentions the alleged theamedes, and the myth of the floating statue.

Camillus Leonardus. *Speculum Lapidum* (Venet., 1502, fol. xxxviii.). An English translation, *The Mirror of Stones*, appeared in London in 1750.

Cornelius Agrippa. *Henrici Cor. Agrippæ ab Nettesheym ... De Occulta Philosophia Libri Tres* (Antv., 1531). The English version *Of the Vanitie and uncertaintie of Artes* was publisht in London, 1569, and again later.

Fallopius (Gabriellus). *G. F. de simplicibus medicamentis purgantibus tractatus* (Venet., 1566). See also his *Tractatus de compositione medicamentorum* (Venet., 1570).

Johannes Langius. *Epistolarum medicinalium volumen tripartitum* (Paris, 1589, p. 792).

Cardinalis Cusanus (Nicolas Khrypffs, Cardinal de Cusa). *Nicolai Cusani de staticis experimentis dialogus* (Argentorati, 1550). The English edition, entitled *The Idiot in four books*, is dated London, 1650.

[9] **Page 3, line 1.** Page 2, line 42. *Marcellus.*—"Marcellus Empiricus, médecin de Théodose-le-Grand, dit que l'aimant, appelé *antiphyson*, attire et repousse le fer." (Klaproth, *Sur l'invention de la boussole*, 1834, p. 12.) The passage from Marcellus runs: "Magnetes lapis, qui antiphyson dicitur, qui ferrum trahit et abjicit, et magnetes lapis qui sanguinem emittit et ferrum ad se trahit, collo alligati aut circa caput dolori capitis medentur." (Marcellus, *de Medicamentis*: in the volume *Medici antiqui omnes, qui latinis literis morborum genera persecuti sunt*. Venet., 1547, p. 89.)

[10] **Page 3, line 11.** Page 3, line 9. *Thomas Erastus.*—The work in question is *Dispvtationvm de Medicina nova Philippi Paracelsi, Pars Prima: in qua quæ de remediis svperstitiosis & Magicis curationibus ille prodidit, præcipuè examinantur à Thoma Erasto in Schola Heydebergensi, professore*. (Basiliæ, 1572. Parts 2 and 3 appeared the same year, and Part 4 in 1573.)

Gilbert had no more love for Paracelsus than for Albertus Magnus or others of the magic-mongers. Indeed the few passages in Paracelsus on the magnet are sorry stuff. They will mostly be found in the seventh volume of his collected works (*Opera omnia*, Frankfurt, 1603). A sample may be taken from the English work publisht in London, 1650, with the title: *Of the Nature of Things, Nine Books; written by Philipp Theophrastus of Hohenheim, called Paracelsvs*.

"For any Loadstone that Mercury hath but touched, or which hath been smeered with Mercuriall oyle, or only put into Mercury will never draw Iron more" (p. 23).

"The life of the Loadstone is the spirit of Iron; which may bee extracted, and taken away with spirit of Wine" (p. 32).

[11] **Page 3, line 13.** Page 3, line 11. *Encelius* (or *Entzelt*, Christoph) wrote a work {8}
publisht in 1551 at Frankfurt, with the title *De re metallica, hoc est, de origine, varietate, et natura corporum metallicorum, lapidum, gemmarum, atque aliarum quæ ex fodinis*

eruuntur, rerum, ad medicine usum deservientium, libri iii. This is written in a singular medley of Latin and German. Gilbert undoubtedly took from it many of his ideas about the properties of metals. See the note to p. **27** on *plumbum album*.

[12] **Page 3, line 20.** Page 3, line 21. *Thomas Aquinas.*—The reference is to his commentaries upon the *Physica* of Aristotle. The passage will be found on p. 96 *bis* of the Giunta edition (Venet., 1539). The essential part is quoted by Gilbert himself on p. **64**.

[13] **Page 3, line 39.** Page 3, line 45. *pyxidem.*—The word *pyxis*, which occurs here, and in the next sentence as *pyxidem nauticam*, is translated *compass*. Eleven lines lower occurs the term *nautica pyxidula*. This latter word, literally the "little compass," certainly refers to the portable compass used at sea. Compare several passages in Book IV. where a contrasting use is made of these terms; for example, on pp. **177** and **202**. Calcagninus, *De re nautica*, uses the term *pyxidecula* for an instrument which he describes as "vitro intecta." On p. **152**, line **9**, Gilbert uses the non-classical noun *compassus*, "boreale lilium compassi (quod Boream respicit)," and again on p. **178**, line **3**.

[14] **Page 4, line 2.** Page 4, line 2. *Melphitani.*—The inhabitants of Amalfi in the kingdom of Naples. The claim of the discovery or invention of the mariners' compass in the year 1302 by one Joannes Goia, or Gioia, also named as Flavio Goia, has been much disputed. In Guthrie's *New System of Modern Geography* (London, 1792, p. 1036), in the Chronology, is set down for the year 1302:

"The mariner's compass invented, or improved by Givia, of Naples. The flower de luce, the arms of the Duke of Anjou, then King of Naples, was placed by him at the point of the needle, in compliment to that prince."

In 1808 an elaborate treatise was printed at Naples, by Flaminius Venanson with the title, *De l'invention de la Boussole Nautique*. Venanson, who cites many authorities, endeavours to prove that if Gioia did not discover magnetic polarity he at least invented the compass, that is to say, he pivotted the magnetic needle and placed it in a box, with a card affixed above it divided into sixteen parts bearing the names of the sixteen principal winds. He alleges in proof that the compass-card is emblazoned in the armorial bearings of the city of Amalfi. This view was combatted in the famous letter of Klaproth to Humboldt publisht in Paris in 1834. He shows that the use of the magnetized needle was known in Europe toward the end of the twelfth century; that the Chinese knew of it and used it for finding the way on land still earlier; that there is no compass-card in the arms of the city of Amalfi; but he concedes that Gioia may have improved the compass in 1302 by adding the wind-rose card. The most recent contributions to the question are a pamphlet by Signorelli, *Sull' invenzione della Bussola nautica, ragionamento di Pietro Napoli Signorelli, segretario perpetuo della Società Pontaniana; letto nella seduta del 30 settembre 1860*; Matteo Camera's *Memorie Storico-diplomatiche dell' antica città e ducato di Amalfi* (Salerno, 1876); and Admiral Luigi Fincati's work *Il Magnete, la Calamita, e la Bussola* (Roma, 1878). An older mention of Gioia is to be found in Blundevile's *Exercises* (3rd edition, 1606, pp. 257-258). See also Crescentio *della Nautica Mediterranea*, (Roma, 1607, p. 253), and Azuni, *Dissertazione sull' origine della bussola nautica* (Venezia, 1797). {9}

There appears to be a slip in Gilbert's reference to Andrea Doria, as he has confounded the town of Amalfi in Principato Citra with Melfi in Basilicata.

One of the sources relied upon by historians for ascribing this origin of the compass is the *Compendia dell' Istoria del Regno di Napoli*, of Collenuccio (Venet., MDXCI.), p. 5.

"Nè in questo tacerò Amalfi, picciola terra, & capo della costa di Picentia, alia quale tutti quelli, che'l mar caualcano, vfficiosamente eterno gratie debono referire, essendo prima in quella terra trovato l'vso, & l'artificio della calamita, & del bussolo, col quale i nauiganti, la stella Tramontana infallibilmente mirando, direzzano il lor corso, si come è publica fama, & gli Amalfitani si gloriano, nè senza ragione dalli piu si crede, essendo cosa certa, che gli antichi tale instromento non hebbero; nè essendo mai in tutto falso quello, che in molto tempo è da molti si diuolga."

Another account is to be found in the *Historiarum sui temporis*, etc., of Paulus Jovius (Florent., 1552), tom. ii., cap. 25, p. 42.

"Quum essem apud Philippum superuenit Ioachinus Leuantius Ligur a Lotrechio missus, qui deposceret captiuos; sed ille negauit se daturum, quando eos ad ipsum Andream Auriam ammirantem deducendos esse iudicaret. Vgonis uerò cadauer, ut illudentium Barbarorum contumeliis eriperetur, ad Amalphim urbem delatum est, in ædeque Andreæ apostoli, tumultuariis exequiis tumulatum. In hac urbe citriorum & medicorum odoratis nemoribus æquè peramœna & celebri, Magnetis usum nauigantibus hodie familiarem & necessarium, adinuentum suisse incolæ asserunt."

Flavius Blondus, whom Gilbert cites, gives the following reference, in which Gioia's name is not mentioned, in the section upon Campania Felix of his Italy (*Blondi Flavii Forlinensis ... Italia Illustrata*, Basiliæ, 1531, p. 420).

"Sed fama est qua Amalphitanos audiuimus gloriari, magnetis usum, cuius adminiculo nauigantes ad arcton diriguntur, Amalphi suisse inuentum, quicquid uero habeat in ea re

ueritas, certû est id noctu nauigandi auxilium priscis omnino suisse incognitum."

There is a further reference to the alleged Amalphian in Caelius Calcagninus *De re nautica commentatio*. (*See Thesaurus Græcarum Antiquitatum*, 1697, vol. xi., p. 761.) On the other hand Baptista Porta, who wrote in Naples in 1558 (*Magia Naturalis*) distinctly sets aside the claim as baseless.

William Barlowe, in *The Navigators Supply* (1597, p. A3), says: "Who was the first inuentor of this Instrument miraculous, and endued, as it were, with life, can hardly be found. The lame tale of one *Flauius* at *Amelphis*, in the kingdome of *Naples*, for to haue deuised it, is of very slender probabilitie. *Pandulph Collenutius* writing the Neapolitane historie telleth vs, that they of *Amelphis* say, it is a common opinion there, that it was first found out among them. But *Polidore Virgil*, who searched most diligently for the Inuentors of things, could neuer heare of this opinion (yet himselfe being an Italian) and as he confesseth in the later ende of his third booke *de inventoribus rerum*, could neuer vnderstand anything concerning the first inuention of this instrument."

According to Park Benjamin (*Intellectual Rise in Electricity*, p. 146) the use of the pivotted compass arose and spread not from Amalfi at the hands of Italians in the fourteenth century, but from Wisbuy, at the hands of the Finns, in the middle of the twelfth century. {10}

Hakewill (*An Apologie or Declaration of the Power and Providence of God*, London, 1673, pp. 284-285) says:

"But *Blondus*, who is therein followed by *Pancirollus*, both *Italians*, will not haue *Italy* loose the praise thereof, telling vs that about 300 yeares agoe it was found out at Malphis or Melphis, a Citty in the Kingdome of *Naples* in the *Province* of *Campania*, now called *Terra di Lovorador*. But for the Author of it, the one names him not, and the other assures vs, he is not knowne: yet *Salmuth* out of *Ciezus & Gomara* confidently christens him with the name of *Flavius*, and so doth *Du Bartas* in those excellent verses of his touching this subject.

> "'W' are not to *Ceres* so much bound for bread,
> Neither to *Bacchus* for his clusters red,
> As Signior *Flavio* to thy witty tryall,
> For first inventing of the Sea-mans dyall,
> Th' vse of the needle turning in the same,
> Divine device, O admirable frame!'

"It may well be then that *Flavius* the *Melvitan* was the first inventor of guiding the ship by the turning of the needle to the *North*: but some *German* afterwards added to the *Compasse* the 32 points of the winde in his owne language, whence other Nations haue since borrowed it."

[15] **Page 4, line 14.** Page 4, line 14. *Paulum Venetum*.—The reference is to Marco Polo. He returned in 1295 from his famous voyage to Cathay. But the oft-repeated tale that he first introduced the knowledge of the compass into Europe on his return is disposed of by several well-established facts. Klaproth (*op. citat.*, p. 57) adduces a mention of its use in 1240 in the Eastern Mediterranean, recorded in a work written in 1242 by Bailak of Kibdjak. And the passages in the Iceland Chronicle, and in Alexander of Neckham are still earlier.

[16] **Page 4, line 17.** Page 4, line 17. *Goropius*. See *Hispanica Ioannis Goropii Becani* (Plantin edition, Antv., 1580), p. 29. This is a discussion of the etymologies of the names of the points of the compass: but is quite unauthoritative.

[17] **Page 4, line 23.** Page 4, line 26. *Paruaim*.—Respecting this reference, Sir Philip Magnus has kindly furnisht the following note. A clue to the meaning of *Parvaim*, which should be written in English letters with a *v*, not a *u*, will be found in *2 Chronicles*, iii. 6. In the verse quoted the author speaks of gold as the gold of Parvaim, וְזָהָב פַּרְוָיִם Parvaim is taken as a gold-producing region. It is regarded by some as the same as Ophir. The word is supposed to be cognate with a Sanskrit word *pûrva* signifying "prior, anterior, oriental." There is nothing in the root indicating gold. A form similar to Parvaim, and also a proper name, is Sepharvaim, found in *2 Kings*, xix. 13, and in *Isaiah*, xxxvii. 13, and supposed to be the name of a city in Assyria.

[18] **Page 4, line 35.** Page 4, line 41. Cabot's observation of the variation of the compass is narrated in the *Geografia* of Livio Sanuto (Vinegia, 1588, lib. i., fol. 2). See also Fournier's *Hydrographie*, lib. xi., cap. 10.

[19] **Page 4, line 36.** Page 4, line 42. *Gonzalus Oviedus*.—The reference is to Gonzalo Fernandez de Oviedo y Valdès. *Summario de la Historia general y natural de las Indias occidentales*, 1525, p. 48, where the author speaks of the crossing of "la linea del Diametro, donde las Agujas hacen la diferencia del Nordestear, ò Noroestear, que es el parage de las Islas de los Açores." {11}

[20] **Page 5, line 8.** Page 5, line 11. *Petri cujusdam Peregrini*.—This opusculum is the famous letter of Peter Peregrinus written in 1269, of which some twenty manuscript

copies exist in various libraries in Oxford, Rome, Paris, etc., and of which the oldest printed edition is that of 1558 (Augsburg). See also Libri, *Histoire des Sciences Mathématiques* (1838); Bertelli in Boncompagni's *Bull. d. Bibliogr.* T. I. and T. IV. (1868 and 1871), and Hellmann's *Rara Magnetica* (1898). A summary of the contents of Peregrinus's book will be found in Park Benjamin's *Intellectual Rise in Electricity* (1895), pp. 164-185.

[21] **Page 5, line 12.** Page 5, line 15. *Johannes Taisner Hannonius.*—Taisnier, or Taysnier, of Hainault, was a plagiarist who took most of the treatise of Peregrinus and publisht it in his *Opusculum... de Natura Magnetis* (Coloniæ, 1562), of which an English translation by Richard Eden was printed by R. Jugge in 1579.

[22] **Page 5, line 18.** Page 5, line 23. *Collegium Conimbricense.*—This is a reference to the commentaries on Aristotle by the Jesuits of Coimbra. The work is *Colegio de Coimbra da Companhia de Jesu, Cursus Conimbricensis in Octo libros Physicorum* (Coloniæ, sumptibus Lazari Ratzneri, 1599). Other editions: Lugd. 1594; and Colon., 1596. The later edition of 1609, in the British Museum, has the title *Commentariorum Collegii Conimbricensis in octo libros physicorum*.

[23] **Page 5, line 25.** Page 5, line 31. *Martinus Cortesius.*—His *Arte de Navegar* (Sevilla, 1556) went through various editions in Spanish, Italian, and English. Eden's translation was publisht 1561, and again in 1609.

[24] **Page 5, line 26.** Page 5, line 33. *Bessardus.*—Toussaincte de Bessard wrote a treatise, *Dialogue de la Longitude* (Rouen, 1574), which gives some useful notes of nautical practice, and of the French construction of the compass. Speaking of the needle he says: "Elle ne tire pas au pole du monde: ains regarde, au Pole du Zodiaque, comme il sera discoursu, cy apres" (p. 34). On p. 50 he speaks of "l'aiguille Aymantine." On p. 108 he refers to Mercator's *Carte Générale*, and denies the existence of the alleged loadstone rock. On p. 15 he gives the most naïve etymologies for the terms used: thus he assigns as the derivation of *Sud* the Latin *sudor*, because the south is hot, and as that of *Ouest* that it comes from *Ou* and *Est*. "Come, qui diroit, Ou est-il? à scauoir le Soleil, qui estoit nagueres sur la terre."

[25] **Page 5, line 28.** Page 5, line 35. *Jacobus Severtius.*—Jacques Severt, whose work, *De Orbis Catoptrici sev mapparvm mvndi principiis descriptione ac usu libri tres* (Paris, 1598), would have probably lapsed into obscurity, but being just newly publisht was mentioned by Gilbert for its follies.

[26] **Page 5, line 30.** Page 5, line 38. *Robertus Norman.*—Author of the rare volume *The Newe Attractiue*, publisht in London, 1581, and several times reprinted. This work contains an account of Norman's discovery of the Dip of the magnetic needle, and of his investigation of it by means of the Dipping-needle, which he invented. He was a compassmaker of the port of London, and lived at Limehouse.

[27] **Page 5, line 32.** Page 5, line 40. *Franciscus Maurolycus.*—The work to which the myth of the magnetic mountains is thus credited is, *D. Francisci Abbatis Messanensis Opuscula Mathematica*, etc. (Venet, MDLXXV, p. 122a). "Sed cur sagitta, vel obelus à vero Septentrione, quandoque ad dextram, quandoque ad sinistram declinat? An quia sagitta, {12}
sicut magnes (cuius est simia) non verum Septentrionem, sed insulam quandam (quam Olaus Magnus Gothus in sua geographia vocat insulam magnetum) semper ex natura inspicere cogitur?"

[28] **Page 5, line 35.** Page 5, line 43. *Olaus Magnus.*—The famous Archbishop of Upsala, who wrote the history of the northern nations (*Historia de Gentibus Septentrionalibus*), of which the best edition, illustrated with many woodcuts, appeared in Rome in 1555. An English edition entitled *A Compendious History of the Goths, Swedes, and Vandals, and Other Northern Nations* was printed in London in 1658; but it is much abbreviated and has none of the quaint woodcuts. The reference on p. **5** appears to be to the following passage on p. 409 (ed. 1555). "Demum in suppolaribus insulis magnetum montes reperiuntur, quorum fragmentis ligna fagina certo tempore applicata, in saxeam duritiem, et vim attractivam convertuntur," or the following on p. 89: "Magnetes enim in extremo Septentrionis veluti montes, unde nautica directio constat, reperiuntur: quorum etiam magnetum tam vehemens est operatio, ut certis lignis fagineis conjuncti, ea vertunt in sui duritiem, & naturam attractivam." On p. 343 is a woodcut depicting the penalties inflicted by the naval laws upon any one who should maliciously tamper with the compass or the loadstone, "qui malitiosè nauticum gnomonem, aut compassum, & præcipuè portionem magnetis, unde omnium directio dependet, falsaverit." He was to be pinned to the mast by a dagger thrust through his hand. It will be noted that the ships carried both a compass, and a piece of loadstone wherewith to stroke the needle.

There is in the Basel edition of this work, 1567, a note *ad lectorem*, on the margin of Carta 16a, as follows:

"Insula 30 milliarium in longitud. & latitud. Polo arctico subjecta.

"Vltra quam directorium nauticum bossolo dicũ uires amittit: propterea quòd ilia insula plena est magnetum."

This myth of the magnetic mountains, probably originating with Nicander, appears, possibly from an independent source, in the East, in China, and in the tales of the Arabian Nights.

Ptolemy gives the following account in his *Geographia* (lib. vii., cap. 2):

Φέρονται δὲ καὶ ἄλλαι συνεχεῖς δέκα νῆσοι καλούμεναι Μανίολαι ἐν ἄις φάσι τὰ σιδήρους ἔχοντα ἥλους πλοῖα κατέχεσθαι, μήποτε τῆς Ἡρικλείας λίθου περὶ αὐτὰς γενομένης, καὶ διὰ τοῦτο ἐπιούροις ναυπηγεῖσθαι. Some editions omit the name of the Manioles from the passage.

No two authorities agree as to the place of these alleged magnetic mountains. Some place them in the Red Sea. Fracastorio, *De Sympathia et Antipathia*, cap. 7 (*Opera omnia*, Giunta edition, 1574, p. 63), gives the following reason for the variation of the compass:

"Nos igitur diligentius rem considerãtes dicimus causam, q̃ perpendiculum illud ad polum vertatur, esse montes ferri, & magnetis, qui sub polo sunt, vt negociatores affirmant, quorum species per incredibilem distantiam vsque ad maria nostra propagata ad perpendiculum vsq;, vbi est magnes, consuetam attractionem facit: propter distantiam autem quum debilis sit, non moueret quidem magnetem, nisi esset in perpendiculo: quare & si non trahit vsq; ac. principium, vnde effluxit, at mouet tamẽ, & propinquiorem facit, quo potest. Quod si naues sorte vllæ propinquiores sint illis montibus, ferrum omne earũ cuellitur, propter quod nauigijs incolæ vtuntur clauis ligneis astrictis."

In the last chapter of his *De Sympathia*, Fracastorio returns to the subject in consequence of some doubts expressed by Giambattista Rhamnusio, seeing that the loadstones in the Island of Elba do not sensibly deflect the magnet. Fracastorio replies thus (p. 76, *op. citat.*): {13}

"Primum igitur vtrum sub Polo sint. Magnetis mõtes, nec ne, sub ambiguo relinquamus, scimus enim esse, qui scribãt planas magis esse eas regiones, de quo Paulus Iouius Ep̃us Nucerinus Luculẽtus historiarũ nostri tẽporis scriptor, circa eã Sarmatiæ partem, quæ Moscouia nũc dicitur, diligentẽ inquisitionem ab incolis fecit, qui ne eos etiã inueniri montes retulere, qui Rhyphei ab antiquis dicti sunt: meminimus tamẽ nos quasdam chartas vidisse earum, quas mundi mappas appellãt, in quibus sub polo montes notati erant (qui Magnetis montes inscripti fuerant). Siue igitur sint, siue non sint ij montes, nihil ad nos in præsentiarum attinet, quando per montes polo subiectos cathenam illam montium intelligimus, qui ad septentrionem spectant tanti, & tam vasti, ac Ferri & Magnetis feraces: qui, & si magis distant à nostro mari, q̃ Iluæ insulæ montes, potentiores tamen sunt ad mouendum perpendiculum propter abundantiam & copiã Ferri, & Magnetis. Fortasse autem, & qui in Ilua est Magnes, non multæ actionis est in ea minera: multi enim dũ in minera sunt, minus valent, q̃ extracti, q̃ spirituales species sua habeant impedimenta: signum autem parum valere in sua minera Iluæ insulæ Magnetem, q̃ tam propinquus quum sit nauigijs illac prætereuntibus, perpendiculum tamen non ad se cõuertit."

Aldrovandi in the *Musæum Metallicum* (Bonon., 1648, p. 554) gives another version of the fable:

"Nonnulli, animadversa hac Magnetis natura, scripserunt naves, quibus in Calecutanam regionem navigatur, clavis ferreis non figi, ob magneticorum frequentiam scopulorum, quoniam facilè dissolverentur. Sed Garzias in Historia Aromatum id fabulosum esse tradidit: quandoquidem plures naues Calecutanæ regionis, & illius tractus, ferreis clauis iunctas obseruauit: immò addidit naues in insulis Maldiuis ligneis quidem clauis copulari, non quia à Magnete sibi metuant, sed quoniam ferri inopia laborant."

According to Aldrovandi (p. 563, *op. citat.*) the magnetic mountains are stated by Sir John Mandeville to be in the region of Pontus.

Lipenius in his *Navigatio Salomonis Ophritica illustrata* (Witteb., 1660), which is a mine of curious learning, in discussing the magnetic mountains quotes the reply of Socrates to the inquirer who asked him as to what went on in the infernal regions, saying that he had never been there nor had he ever met any one who had returned thence.

The loadstone rock figures in several early charts. In Nordenskiöld's *Facsimile Atlas* (Stockholm, 1889) is given a copy of the Map of Johan Ruysch from an edition of Ptolemy, publisht in Rome in 1508, which shows four islands within the ice-bound Arctic regions. South of these islands and at the east of the coast of Greenland is the inscription: *Hic compassus navium non tenet, nec naves quæ ferrum tenent revertere valent.* To which (on p. 63) Nordenskiöld adds the comment: *Sagan on magnetberg, som skulle draga till sig fartyg förande jern, är gamal.* And he recalls the reference of Ptolemy to the magnetic rocks in the Manioles. A second inscription is added to Ruysch's map in the ornamental margin that borders the Arctic islands. *Legere est in libro de inventione fortunati sub polo arctico rupem esse excelsam ex lapide magnete 33 miliarium germanorum ambitu.* This refers to a matter recorded in Hakluyt's *Principall Navigations* (Lond., 1589, p. 249), namely: "A Testimonie of the learned Mathematician, maister John Dee, touching the foresaid voyage of Nicholas de Linna. Anno 1360 a frier of Oxford, being a good Astronomer, went in companie with others to the most Northren islands of the world, and there leaving his company together, he travelled alone, and purposely described all the {14}

Northern islands, with the indrawing seas: and the record thereof at his return he delivered to the king of England. The name of which booke is *Inventio Fortunata* (*aliter fortunæ*) *qui liber incipit a gradu 54 usq. ad polum*."

The situation of the alleged loadstone rock is thus described by T. Blundevile in his *Exercises* in the chapter entitled *A plaine and full description of Peter Plancius his vniuersall Map, seruing both for sea and land, and by him lately put foorth in the yeare of our Lord, 1592*.... Written in our mother tongue by M. Blundeuill, Anno Domini 1594. The passage is quoted from p. 253 of the third edition (1606):

"Now betwixt the 72. and 86. degrees of North latitude he setteth downe two long Ilands extending from the West towardes the East somewhat beyond the first Meridian, and from the saide Meridian more Eastward he setteth downe other two long Ilandes ... and hee saith further that right under the North pole there is a certaine blacke and most high rocke which hath in circuite thirtie and three leagues, which is nintie and nine miles, and that the long Iland next to the Pole on the West is the best and most healthfull of all the North parts. Next to the foresaide Ilandes more Southward hee setteth downe the Ilandes of Crocklande and Groynelande, making them to haue a farre longer and more slender shape then all other mappes doe.... Moreouer at the East end of the last Ilande somewhat to the Southwarde, he placeth the Pole of the Lodestone which is called in Latine Magnes, euen as Mercator doth in his Mappe who supposing the first Meridian to passe through Saint Marie or Saint Michael, which are two of the outermost Ilandes of the Azores Eastwarde, placeth the Pole of the stone in the seuentie fiue degree of Latitude, but supposing the first Meridian to passe through the Ile Coruo, which is the furthest Ile of the Azores Westwarde, he placeth the Pole of the Lodestone in the seuentie seuen degree of Latitude."

Further, in the chapter on *The Arte of Nauigation* in the same work (p. 332, *ed. citat.*), Blundevile says:

"But whereas Mercator affirmeth that there should bee a mine or great rocke of Adamant, wherunto all other lesser rockes or Needles touched with the Lodestone doe incline as to their chiefe fountaine, that opinion seemeth to mee verie straunge, for truely I rather beleeue with Robert Norman that the properties of the Stone, as well in drawing steele, as in shewing the North Pole, are secret vertues given of GOD to that stone for mans necessarie vse and behoofe, of which secrete vertues no man is able to shewe the true cause."

The following is one of the inscriptions in the compartments of the great Chart of Mercator entitled *Ad Usum Navigantium*, published in 1569:

"Testatur Franciscus Diepanus peritissimus nauarchus volubiles libellas, magnetis virtute infectas recta mundi polum respicere in insulis C. Viridis, Solis, Bonauista, et Maio, cui proxime astipulantur qui in Tercera, aut S. Maria (insulæ sunt inter Açores) id fieri dicunt, pauci in earundem occidentalissima Corvi nomine id contingere opinantur. Quia vero locorum longitudinis a communi magnetis et mundi meridiano iustis de causis initium sumere oportet, plurium testimonium sequutus primum meridianum per dictas C. Viridis insulas protraxi, et quum alibi plus minusque a polo deuiante magnete polum {15}
aliquum peculiarem esse oporteat quo magnetes ex omni mundi parte despiciant, euum hoc quo assignaui loco existere adhibita declinatione magnetis Ratisbonæ obseruata didici. Supputaui autem eius poli situm etiam respectu insulæ Corui, ut iuxta extremo primi meridiani positus extremi etiam termini, intra quos polum hunc inueniri necesse est, conspicui fierent, donec certius aliquod nauclerorum obseruatio attulerit."

Not all the map-makers were as frank as Paulus Merula, the author of a *Cosmographia Generalis*, printed by Plantin in 1605, at Leyden. For in the description of his *tabula universalis* (*op. citat.* lib. iii., cap. 9) he says that he does not believe in the magnetic islands; but that he has put them into his chart lest unskilful folk should think that he had been so careless as to leave them out!

In the well-known myth of Ogier the Dane, immortalized by William Morris in the *Earthly Paradise* (London, 1869, vol. i., p. 625), the loadstone rock is an island in the far North. But this story is not one of the Scandinavian sagas, and belongs to the Carlovingian cycle of heroic poems, of which the chief is the *Chanson de Roland*; and Ogier le Danois is really not a Dane but an *Ardennois*.

In the Middle-High German epic of Kudrun, the adventures of the fleet of Queen Hilda when attracted by the loadstone mountain at Givers, in the North Sea, are narrated at some length. (See *Kudrun, herausgegeben und erklärt von Ernst Martin*. Halle, 1872.) One stanza will serve as a sample:

1126. Ze Givers vor dem berge | lac daz Hilden her.
swie guot ir anker wæren, | an daz vinster mer.
magnêten die steine | heten si gezogen.
ir guote segelboume | stuonden alle gebogen.

which may be rendered:

1126. At Givers before the mountain | lay Hilda's ships by.
Though good their anchors were, | upon the murky sea.
Magnets the stones were | had drawn them thither.
Their good sailing masts | stood all bent together.

Recent magnetic research has shown that while there are no magnetic mountains that would account for the declination of the compass in general, yet there are minor local variations that can only be accounted for by the presence of magnetic reefs or rocks. The reader is referred to the account of the magnetic survey of Great Britain in the *Philosophical Transactions* (1890) by Professors Rücker and Thorpe. The well-known rocky peak the Riffelhorn above Zermatt, in Switzerland, produces distinct perturbations in the direction of the compass within half a mile of its base. Such local perturbations are regularly used in Sweden for tracing out the position of underground lodes of iron ore. See Thalén, *Sur la Recherche des Mines de Fer à l'aide de Mesures magnétiques* (Soc. Royale des Sciences d'Upsal, 1877); or B. R. Brough, *The Use of the Magnetic Needle in exploring for Iron Ore* (*Scientific American*, Suppl. No. 608, p. 9708, Aug. 27, 1887).

Quite recently Dr. Henry Wilde, F.R.S., has endeavoured to elucidate the deviations of the compass as the result of the configurations of land and sea on the globe, by means of a model globe in which the ocean areas are covered with thin sheet iron. This apparatus Dr. Wilde calls a *Magnetarium*. See *Proc. Roy. Soc.*, June, 1890, Jan., 1891, and June, 1891. An actual magnetic rock exists in Scandinavia, the following account of it being given in the *Electrical Review* of New York, May 3, 1899: {16}

"The island of Bornholm in the Baltic, which consists of a mass of magnetic iron ore, is much feared by mariners. On being sighted they discontinue steering by compass, and go instead by lighthouses. Between Bornholm and the mainland there is also a dangerous bank of rock under water. It is said that the magnetic influence of this ore bank is so powerful that a balanced magnetic needle suspended freely in a boat over the bank will take a vertical position."

[29] **Page 5, line 35.** Page 5, line 43. *Josephus Costa.*—This is unquestionably a misprint for *Acosta* (Joseph de), the Jesuit, whose work *Historia natural y moral de las Indias* was publisht at Seville in 1590. An Italian edition appeared at Venice in 1596. The English edition, translated by E. Grimestone, *The Naturall and Morall Historie of the East and West Indies*, was publisht in London in 1604 and 1878. There are in Gilbert's book references to two writers of the name of Costa or Costæus, Joannes Costa of Lodi, who edited Galen and Avicenna (see pp. **3** and **62**), and Filippo Costa of Mantua, who wrote on antidotes and medicaments (see p. **141**). The passage to which Gilbert refers is in Acosta's *Historia* (ed. 1590, p. 64).

"Deziame a mi vn piloto muy diestro Portugues q̃ eran quatro puntos en todo el orbe, donde se afixaua el aguja con el Norte, y contaualas por sus nombres, de que no me acuerdo bien. Vno destos es el paraje de la Isla del Cueruo, en las Terceras, o Islas de Açores, como es cosa y a muy sabida. Passando di alli a mas altura, Noruestea, que es dezir, q̃ declina al Poniente ... que me digã la causa desta efecto?... Porque vn poco de hierro de fregarse cõ la piedra Iman ...

"Mejor es, como dize Gregorio Theologo, que a la Fe se sujete la razon, pues aun en su casa no sabe bien entenderse...."

[30] **Page 5, line 36.** Page 5, line 45. *Livius Sanutus.*—Livio Sanuto publisht at Venice in 1588 a folio work, *Geografia distinta in xii Libri; ne' quali, oltre l'esplicatione di nostri luoghi di Tolomeo, della Bussola e dell' Aguglia, si dichiarono le provincie ... dell' Africa*. In this work all Liber i. (pages 1-13) deals with observations of the compass, mentioning Sebastian Cabot, and other navigators. He gives a map of Africa, showing the central lakes out of which flow the *Zaires fluvius* and the *Zanberes fluvius*.

[31] **Page 6, line 2.** Page 6, line 5. *Fortunius Affaitatus.*—The work of Affaytatus, *Physicæ ac astronomiæ considerationes*, was publisht in Venice in 1549.

[32] **Page 6, line 3.** Page 6, line 6. *Baptista Porta.*—The reference is to his celebrated *Magia naturalis*, the first edition of which came out in 1558 at Naples. An English edition, *Natural Magick by John Baptista Porta, a Neapolitaine*, was printed in London, 1658. Book seven of this volume treats "Of the wonders of the Load-stone." In the proem to this book Porta says: "I knew at Venice R. M. Paulus, the Venetian, that was busied in the same study: he was Provincial of the Order of servants, but now a most worthy Advocate, from whom I not only confess, that I gained something, but I glory in it, because of all the men I ever saw, I never saw any man more learned, or more ingenious, having obtained the whole body of learning; and is not only the Splendor and Ornament of Venice or Italy, but of the whole world." The reference is to Fra Paolo Sarpi, better known as the historian of the Council of Trent. Sarpi was himself known to Gilbert. {17}

His relations with Gilbert are set forth in the memoir prefixt to the edition of his works, *Opere di Fra Paolo Sarpi, Servita* ... in Helmstat, MDCCLXI, p. 83. "Fino a questi giorni continuava il Sarpi a raccorre osservazioni sulla declinazione dell' Ago Calamitato; e poi ch' egli, atteso il variare di tal declinazione, assurdità alcuna non trovava riguardo al pensamento dell' Inglese Guglielmo Gilberto, cioè, che l'interno del nostro Globo fosse

gran Calamita...." Here follows a quotation from a letter of Sarpi to Lescasserio:

"... Unde cuspidem trahi a tanta mole terrena, quæ supereminet non absurde putavit Gullielmus Gilbertus, et in eo meridiano respicere recta polum, cave putes observatorem errasse. Est Vir accuratissimus, et interfuit omnibus observationibus, quas plures olim fecimus, et aliquas in sui gratiam, et cum arcubus vertici cupreo innitentibus, et cum innatantibus aquæ, et cum brevibus, et cum longis, quibus modis omnibus et Hierapoli usus suit."

Sarpi had correspondence with Gilbert, Bacon, Grotius, and Casaubon. He also wrote on magnetism and other topics *in materia di Fisica*, but these writings have perisht. He appears to have been the first to recognize that fire destroyed the magnetic properties. (See *Fra Paolo Sarpi, the greatest of the Venetians* by the Rev. Alexander Robertson, London, 1894; see also the notice of Sarpi in Park Benjamin's *Intellectual Rise in Electricity*.)

[33] **Page 6, line 7.** Page 6, line 11.: *R. M. Paulus Venetus*. See preceding note.

[34] **Page 6, line 21.** Page 6, line 28.: *Franciscus Rueus*.—Francois de la Rue, author of *De Gemmis Aliquot* ... (Paris, 1547). Amongst other fables narrated by Rueus is that if a magnet is hung on a balance, when a piece of iron is attracted and adheres to the magnet, it adds nothing to the weight!

[35] **Page 6, line 25.** Page 6, line 33.: *Serapio*.—This account of the magnetic mountains will be found in an early pharmacology printed in 1531 (Argentorati, G. Ulricher Andlenus), with the title "In hoc volumine continetur insignium medicorum Joan. Serapionis Arabis de Simplicibus Medicinis opus præclarum et ingens, Averrois Arabis de eisdem liber eximius, Rasis filius Zachariæ de eisdem opusculum perutile." It was edited by Otho Brunsels. Achilles P. Gasser, in his Appendix to the Augsburg edition of Peregrinus, gives a reference to Serapio Mauritanus, parte 2, cap. 394, libri *de medicinis compositis.*

[36] **Page 6, line 30.** Page 6, line 39.: *Olaus Magnus*. See note to p. **5**.

[37] **Page 6, line 34.** Page 6, line 44.: *Hali Abas*.—A reference is given in Gasser's (1558) edition of Peregrinus to Haliabbas Arabs, lib. 2, *practicæ* cap. 45, *Regalis Dispositionis Medicinæ*. The passage to which Gilbert refers is found in the volume *Liber totius medicinæ necessaria cõtinens ... quem Haly filius Abbas ... edidit ... et a Stephano ex arabica lingua reductus*. (Lugd., 1523, 4to.) Liber Primus. Practice, Cap xlv. *de speciebus lapidum*, § 466. "Lapis magnetes filis e v̄tute sadenego: & aiunt q̄m si teneat^{r} in manu mitigat q̄ sunt in pedib^{s} ipis dolores ac spasmū."

Mr. A. G. Ellis identifies the noun *sadenegum* as a Latin corruption of the Arabic name of hæmatite, *shâdanaj*.

[38] **Page 6, line 36.** Page 6, line 46.: *Pictorius*.—His poem was publisht at Basel, 1567. See also note on Marbodæus, p. 7, line 20, below.

[39] **Page 6, line 36.** Page 7, line 1.: *Albertus Magnus*.—Albertus, the celebrated Archbishop of Ratisbon, is responsible for propagating sundry of the myths of the magnet; and Gilbert never loses a chance of girding at him. The following examples are taken from the treatise *De mineralibus et rebus metallicis* (Liber II. *de lapidibus preciosis*), Venet., 1542. {18}

p. 171. "Et quod mirabile videtur multis his lapis [adamas] quando Magneti supponitur ligat Magnetem et non permittit ipsum ferrum trahere."

p. 193. "Vnctus autẽ lapis alleo non trahit, si superponitur ei Adamas iterum non attrahit, ita quod paruus Adamas magnũ ligat Magnetẽ. Inventus autẽ est nostris tẽporibus Magnes qui ab uno angulo traxit ferrũ et ab alio fugavit, et hunc Aristot. ponit aliud genus esse Magnetis. Narrauit mihi quidam ex nostris sociis experimẽtator quod uidit Federicum Imperatorem habere Magnetem qui non traxit ferrum, sed ferrum uiceuersa traxit lapidem."

The first edition of this work *de mineralibus* appears to have been publisht in Venice as a folio in 1495.

[40] **Page 7, line 9.** Page 7, line 15. *Gaudentius Merula*.—This obscure passage is from Liber IIII., cap. xxi., *Lapides*, of the work *Memorabilium Gaudentii Merulæ...* (Lugd., 1556), where we find:

"Qui magneti vrsæ sculpserit imaginem, quãdo Luna melius illuc aspiciat, & filo ferreo suspẽderit, compos fiet vrsæ cælestis virtutis: verùm cum Saturni radiis vegetetur, satius fuerit eam imaginem non habere: scribunt enim Platonici malos dæmones septentrionales esse" (p. 287).

"Trahit autem magnes ferrum ad se, quod ferro sit ordine superior apud vrsum" (p. 287).

The almost equally obscure passage in the *De triplici vita* of Marsiglio Ficino (Basil., 1532) runs:

"Videmus in specula nautarum indice poli libratum acum affectum in extremitate Magnete moueri ad Vrsam, illuc uidelicet trahente Magnete: quoniam & in lapide hoc præualet uirtus Vrsæ, & hinc transfertur in ferrum, & ad Vrsam trahit utrunq;. Virtus autem eiusmodi tum ab initio infusa est, tum continue Vrsæ radijs uegetatur, Forsitan ita se habet Succinum ad polum alterum & ad paleas. Sed dic interea, Cur Magnes trahit ubiq; ferrum? non quia simile, alioquin & Magnetem Magnes traheret multo magis, ferrumq̄; ferrū: non quia superior in ordine corporum, imò superius est lapillo metallum ... Ego autem quum hæc explorata hactenus habuissem admodum gratulabar, cogitabamq̄; iuuenis adhuc Magneti pro uiribus inscluperet (*sic*) coelestis Vrsæ figuram, quando Luna melius illuc aspiciat, & ferro tūc filo collo suspendere. Sperabam equidem ita demum uirtutis me sideris illius compotem fore," &c. (p. 172).

[41] **Page 7, line 14.** Page 7, line 20. *Ruellius*.—Joannes Ruellius wrote a herbal *De Natura Stirpium*, Paris, 1536, which contains a very full account of amber, and a notice of the magnet (p. 125) and of the fable about garlic. But on p. 530 of the same work he ridicules Plutarch for recording this very matter.

[42] **Page 7, line 20.** Page 7, line 27. *Marbodæus Gallus*.—This rare little book is entitled *Marbodei Galli Poetæ vetustissimi de lapidibus pretiosis Enchiridion*. It was printed at Paris in 1531. The Freiburg edition, also of 1531, has the commentaries of Pictorius. The poem is in Latin hexameters. After a preface of twenty-one lines the virtues of stones are dealt with, the paragraph beginning with a statement that Evax, king of the Arabs, is said to have written to Nero an account of the species, names and colours of stones, their place of origin and their potencies; and that this work formed the basis of the poem. The alleged magical powers of the magnet are recited in Caput I., *Adamas*. Caput XLIII., *Magnes*, gives further myths. The commentary of Pictorius gives references to earlier writers, Pliny, Dioscorides, Bartholomæus Anglicus, Solinus, Serapio, and to the book *de lapidibus* erroneously ascribed to Aristotle. {19}

The following is a specimen of the poem of Marbodeus:

Magnetes lapis est inuentus apud Trogloditas,
Quē lapidā genetrix nihilominus India mittit.
Hic ferruginei cognoscitur esse coloris,
Et ui naturæ uicinum tollere ferrum.
Ededon magus hoc primum ferè dicītur usus,
Conscius in magica nihil esse potentius arte.
Post illum fertur famosa uenefica Circe
Hoc in præstigijs magicis specialiter usa.

This poem was reprinted (1854) in Migne's *Patrologia*. In 1799 Johann Beckmann issued an annotated variorum edition of Marbodeus (*Marbodi Liber Lapidvm sev de Gemmis...*, Göttingæ, 1799), in which there is a bibliography of the poem, the first edition of which appears to have been publisht in 1511, at Vienna, thirteen other editions being described. Beckmann adds many illustrative notes, and a notice of the Arabian Evax, who is supposed to have written the treatise *de lapidibus*. Not the least curious part is a French translation alleged to have been written in 1096, of which Chap. XIX. on the Magnet begins thus:

Magnete trovent Trogodite,
En Inde e precieus est ditte.
Fer resemble e si le trait,
Altresi cum laimant fait.
Dendor lama mult durement.
Qi lusoit a enchantement.
Circe lus a dot mult chere,
Cele merveillose forciere, &c.

[43] **Page 7, line 21.** Page 7, line 28. *echeneidis*.—The *echeneis*, or sucking-fish, reputed to have magical or magnetic powers, is mentioned by many writers. As an example, see Fracastorio, *De Sympathia et Antipathia*, lib. i., cap. 8, *De Echineide, quomodo firmare nauigia possit* (Giunta edition, Venet., 1574, p. 63). For other references to the *Echeneis* see Gaudentius Merula (*op. citat.*) p. 209. Also Dr. Walter Charleton, *Physiologia Epicuro Gassendo-Charltoniana* (Lond., 1654), p. 375. Compare p. **63**, line **3**.

[44] **Page 7, line 33.** Page 7, line 43. *Thomas Hariotus*, etc.—The four Englishmen named were learned men who had contributed to navigation by magnetic observations. Harriot's account of his voyage to Virginia is printed in Hakluyt's *Voyages*. Robert Hues (or Hood) wrote a treatise *on Globes*, the Latin edition of which appeared in 1593 (dedicated to Sir Walter Raleigh), and the English edition in 1638. It was republisht by the Hakluyt Society, 1889. Edward Wright, the mathematician and writer on navigation, also wrote the preface to Gilbert's own book. Abraham Kendall, or Abram Kendal was "Portulano," or sailing-master of Sir Robert Dudley's ship the *Bear*, and is mentioned in Dudley's *Arcano del Mare*. On the return of Dudley's expedition in 1595, he joined Drake's last expedition, which sailed that year, and died on the same day as Drake himself, 28 January, 1596. (See *Hakluyt*, ed. 1809, iv., p. 73.)

[45] **Page 7, line 36.** Page 8, line 1. *Guilielmus Borough.*—Borough's book has the title: *A Discours of the Variation of the Cumpas, or magneticall Needle. Wherein is Mathematically shewed, the manner of the obseruation, effectes, and application thereof, made by W. B.* And is to be annexed to *The Newe Attractive* of R. N., 1581 (London). {20}

[46] **Page 7, line 37.** Page 8, line 2. *Guilielmus Barlo.*—Archdeacon William Barlowe (author, in 1616, of the *Magneticall Aduertisements*) wrote in 1597 a little work called *The Navigators Supply*. It gives a description of the ordinary compass, and also one of a special form of meridian compass provided with sights for taking the bearings by the sun.

[47] **Page 7, line 37.** Page 8, line 3. *Robertus Normannus*. See Note to p. 5.

[48] **Page 8, line 14.** Page 8, line 21. *illo fabuloso Plinij bubulco.*—The following is Pliny's account from Philemon Holland's English version of 1601 (p. 586): "As for the name Magnes that it hath, it tooke it (as *Nicander* saith) of the first inventor and deviser thereof, who found it (by his saying) upon the mountaine Ida (for now it is to be had in all other countries, like as in Spaine also;) and (by report) a Neat-heard he was: who, as he kept his beasts upon the aforesaid mountaine, might perceive as he went up and downe, both the hob-nailes which were on his shoes, and also the yron picke or graine of his staffe, to sticke unto the said stone."

[49] **Page 9, line 22.** Page 9, line 30. *Differentiæ priscis ex colore.*—Pliny's account of the loadstones of different colours which came from different regions is mainly taken from Sotacus. The white magnet, which was friable, like pumice, and which did not draw iron, was probably simply magnesia. The blue loadstones were the best. See p. 587 of Holland's translation of Pliny, London, 1601. St. Isidore (*Originum seu Etymologiarum*, lib. xvi., cap. 4) says: "Omnis autem magnes tanta melior est, quanto [magis] cæruleus est."

[50] **Page 10, line 29.** Page 10, line 42. *Suarcebergo ... Snebergum & Annæbergum.*—In the Stettin editions of 1628 and 1633 these are spelled *Swarcebergs ... Schnebergum & Annebergum*. The Cordus given as authority for these localities is Valerius Cordus, the commentator on Dioscorides.

[51] **Page 11, line 3.** Page 11, line 12. *Adriani Gilberti viri nobilis.*—"Adrian Gylbert of Sandridge in the Countie of Devon, Gentleman" is the description of the person to whom Queen Elizabeth granted a patent for the discovery of a North-West passage to China. See Hakluyt's *Voyages*, vol. iii., p. 96.

[52] **Page 11, line 17.** Page 11, line 28. *Dicitur a Græcis* ηρακλιος.—The discussion of the names of the magnet in different languages by Gilbert in this place is far from complete. He gives little more than is to be found in Pliny. For more complete discussions the reader is referred to Buttmann, *Bemerkungen über die Benennungen einiger Mineralien bei den Alten, vorzüglich des Magnetes und des Basaltes* (Musæum der Alterthumswissenschaft, Bd. II., pp. 5-52, and 102-104, 1808); G. Fournier, *Hydrographie* (livre xi., chap. I, 1643); Ulisse Aldrovandi, *Musæum Metallicum* (Bononiæ, 1648, lib. iv., cap. 2, p. 554); Klaproth, *Lettre à M. le Baron A. de Humboldt, sur l'invention de la Boussole*, Paris, 1834; T. S. Davies, *The History of Magnetical Discovery* (Thomson's *British Annual*, 1837, pp. 250-257); Th. Henri Martin, *De l'Aimant, de ses noms divers et de ses variétés suivant les Anciens* (Mémoires présentés par divers savants a l'Academie des Inscriptions et Belles-lettres, I^{re} série, t. vi., I^{re} partie, 1861); G. A. Palm, *Der Magnet in Alterthum* (Programm des k. württembergischen Seminars Maulbronn, Stuttgart, 1867). Of these works, those of Klaproth and of Martin are by far the most important. {21}
Klaproth states that in modern Greek, in addition to the name μαγνῆτις, the magnet also has the names ἀδάμας and καλαμίτα. The former of these, in various forms, *adamas*, *adamant*, *aimant*, *yman*, and *piedramon*, has gone into many languages. Originally the word ἀδάμας (the unconquered) was applied by the Greeks to the hardest of the metals with which they were acquainted, that is to say, to hard-tempered iron or steel, and it was subsequently because of its root-signification also given by them to the diamond for the same reason; it was even given to the henbane because of the deadly properties of that plant. In the writings of the middle ages, in St. Augustine, St. Isidore, Marbodeus, and even in Pliny, we find some confusion between the two uses of *adamas* to denote the loadstone as well as the diamond. Certainly the word *adamas*, without ceasing to be applied to the diamond, also designated the loadstone. At the same time (says Martin) the word *magnes* was preserved, as Pliny records, to designate a loadstone of lesser strength than the *adamas*. On the other hand, the word *diamas*, or *deamans*, had already in the thirteenth century been introduced into Latin to signify the diamond as distinguisht from the magnet. *Adamas* was rendered *aymant* in the romance version of the poem of Marbodeus on stones (see Beckmann's variorum edition of 1799, p. 102), and in this form it was for a time used to denote both the magnet and the diamond. Then it gradually became restricted in use to the stone that attracts iron.

Some confusion has also arisen with respect to the Hebrew name of the magnet. Sir W. Snow Harris makes the following statement (*Magnetism*, p. 5): "In the Talmud it [the loadstone] is termed *achzhàb'th*, the stone which attracts; and in their ancient prayers it has the European name *magnēs*." On this point Dr. A. Löwy has furnisht the following notes. The loadstone is termed in one of the Talmudical sections and in the Midrash,

Eben Shoebeth (lapis attrahens). This would of course be written אבן שואבת. Omitting the ו which marks the participial construction, the words would stand thus: אבן שאבת A person referring to Buxtorf's *Lexicon* Talmudicum would in the index look out for "Lapis magnesius," or for "magnes." He would then, in the first instance, be referred to the two words already quoted. Not knowing the value of the letters of the Hebrew alphabet, he reads אבן שאבת thus: אכזשאבת achzhab'th. It is true that Buxtorf has inserted in his *Lexicon* the vocable מַגְנִיסס, "corruptum ex gr. μάγνης, μαγνήτης, μαγνῆτις, named after the Asiatic city Magnesia." He goes on to say, "Inde Achilles Statius istum lapidem vocavit μαγνήσιαν λίθον. Hinc אבן המגניסס חמשוך הברזל. Lapis Magnesius trahit ferrum." Here he quotes from (Sepher) Ikkarem IV., cap. 35.

Kircher, in his *Magnes, sive de Arte magnetica* (Coloniæ, 1643), gives several other references to Hebrew literature. Others have supposed that the word חלמיש *khallamish*, which signifies pebble, rock, or hard rock, to be used for the magnet.

As to the other Greek name, σιδηρῖτις, or λίθος σιδηρῖτις this was given not only to the loadstone but also to non-magnetic iron. In the *Etymologicum magnum* (under the word μαγνῆτις), and in Photius (*Quæst. amphiloch.*, q. 131), it is stated that the name *sideritis* was given to the loadstone either because of its action on iron, or of its resemblance in aspect to iron, *or rather*, they say, *because the loadstone was originally found in the mines of this metal*. Alexander of Aphrodisias expressly says (*Quætiones Physicæ*, II. 23) that the loadstone appears to be nothing else than γῆ σιδηρῖτις, the earth which yields iron, or the earth of iron. {22}

[53] **Page 11, line 19.** Page 11, line 29. *ab Orpheo*.—The reference is to v. 301-328 of the Λιθικά. The passage, as given in Abel's edition (Berol., 1881), begins:

> Τόλμα δ' ἀθανάτους καὶ ἐνήεϊ μειλίσσεθαι
> μαγνήσσῃ, τὴν δ' ἔξοχ' ἐφίλατο θούσιος Ἄρης,
> οὕνεκεν, ὁππότε κεν πελάσῃ πολιοῖο σιδήρου,
> ἠύτε παρθενικὴ τερενόχροα χερσὶν ἑλοῦσα
> ἠΐθεον στέρνῳ προσπτύσσεται ἱμεροέντι,
> ὣς ἅγ' ἁρπάζουσα ποτὶ σφετερὸν δέμας αἰεὶ
> ἃψ πάλιν οὐκ ἐθέλει μεθέμεν πολεμιστὰ σὶδηρον.

[54] **Page 11, line 20.** Page 11, line 31. *Gallis aimant*.—The French word *aimant*, or *aymant*, is generally supposed to be derived from *adamas*. Nevertheless Klaproth (*op. citat.*, p. 19) suggests that the word *aimant* is a mere literal translation into French of the Chinese word *thsu chy*, which is the common name of the magnet, and which means *loving stone*, or *stone that loves*. All through the east the names of the magnet have mostly the same signification, for example, in Sanskrit it is *thoumbaka* (the kisser), in Hindustani *tchambak*.

[55] **Page 11, line 20.** Page 11, line 32. *Italis calamita*.—The name *calamita*, universal in Italian for the magnet, is also used in Roumanian, Croatian, Bosnian, and Wendish. Its supposed derivation from the Hebrew *khallamîsh* is repudiated by Klaproth, who also points out that the use of καλαμιτα in Greek is quite modern. He adds that the only reasonable explanation of the word *calamita* is that given by Father Fournier (*op. citat.*), who says:

"Ils (les marins français) la nomment aussi *calamite*, qui proprement en français signifie une *grenouille verte*, parce qu'avant qu'on ait trouvé l'invention de suspendre et de balancer sur un pivot l'aiguille aimantée, nos ancêtres l'enfermaient dans une fiole de verre demi-remplie d'eau, et la faisaient flotter, par le moyen de deux petits fétus, sur l'eau comme une grenouille." Klaproth adds that he entirely agrees with the learned Jesuit, but maintains that the word *calamite*, to designate the little green frog, called to-day *le graisset*, *la raine*, or *la rainette*, is essentially Greek. For we read in Pliny (*Hist. Nat.* lib. xxxii., ch. x.): "Ea rana quam Græci *calamiten* vocant, quoniam inter arundines, fruticesque vivat, minima omnium est et viridissima."

[56] **Page 11, line 20.** Page 11, line 32. *Anglis* loadstone & adamant stone.

The English term *loadstone* is clearly connected with the Anglo-Saxon verb *lædan*, to lead, and with the Icelandic *leider-stein*. There is no doubt that the spelling *lodestone* would be etymologically more correct, since it means *stone that leads* not *stone that carries a load*. The correct form is preserved in the word *lode-star*.

The word *adamant*, from *adamas*, the mediæval word for both loadstone and diamond, also occurs in English for the loadstone, as witness Shakespeare:

> "You draw me, you hard-hearted adamant
> But yet you draw not iron; for my heart
> Is true as steel."
>
> *Midsummer Night's Dream*, Act II, Scene 1.

[57] **Page 11, line 21.** Page 11, line 33. *Germanis magness*, & *siegelstein*. The Stettin edition of 1628 reads *Germanis* **Magnetstein**, *Belgis* **Seylsteen**; while that of 1633 reads *Germanis* **Magnetstein**, *Belgis* **Sylsteen**. {23}

[58] **Page 11, line 26.** Page 11, line 39. In this line the Greek sentence is, in every known copy of the folio of 1600, corrected in ink upon the text, θαλῆς being thus altered into Θαλῆς, and απομνεμονύουσι into απομνεμονεύουσι. Four lines lower, brackets have been inserted around the words (lapidum specularium modo). These ink corrections must have been made at the printers', possibly by Gilbert's own hand. They have been carried out as errata in the editions of 1628 and 1633. The "facsimile" Berlin reprint of 1892 has deleted them, however. Other ink corrections on pp. **14**, **22**, **38**, **39**, **47**, **130**, and **200** of the folio edition of 1600 are noted in due course.

[59] **Page 11, line 29.** Page 11, line 45. *lapis specularis*. This is the mediæval name for *mica*, but in Elizabethan times known as talc or muscovy stone. Cardan, *De Rerum Varietate* (Basil., 1557, p. 418), lib. xiiii., cap. lxxii., mentions the use of *lapis specularis* for windows.

[60] **Page 11, line 31.** Page 11, line 46.: *Germanis Katzensilbar* & *Talke*.—In the editions of 1628 and 1633 this is corrected to *Germanis* **Katzensilber & Talcke**. Goethe, in *Wilhelm Meister's Travels*, calls mica "cat-gold."

[61] **Page 12, line 30.** Page 12, line 35. *integtum* appears to be a misprint for *integrum*, which is the reading of editions 1628 and 1633.

[62] **Page 13, line 4.** Page 13, line 3. μικρόγη *seu Terrella*. Although rounded loadstones had been used before Gilbert's time (see Peregrinus, p. 3 of Augsburg edition of 1558, or Baptista Porta, p. 194, of English edition of 1658), Gilbert's use of the spherical loadstone as a model of the globe of the earth is distinctive. The name *Terrella* remained in the language. In *Pepys's Diary* we read how on October 2, 1663, he "received a letter from Mr. Barlow with a terella." John Evelyn, in his *Diary*, July, 1655, mentions a "pretty terella with the circles and showing the magnetic deviations."

A Terrella, 4½ inches in diameter, was presented in 1662 by King Charles I. to the Royal Society, and is still in its possession. It was examined in 1687 (see *Phil. Transactions* for that year) by the Society to see whether the positions of its poles had changed.

In Grew's *Catalogue and Description of the Rarities belonging to the Royal Society and preserved at Gresham College* (London, 1681, p. 364) is mentioned a Terrella contrived by Sir Christopher Wren, with one half immersed in the centre of a plane horizontal table, so as to be like a Globe with the poles in the horizon, having thirty-two magnet needles mounted in the margin of the table to show "the different respect of the *Needle* to the several *Points* of the *Loadstone*."

In Sir John Pettus's *Fleta Minor*, London, 1683, in the *Dictionary of Metallick Words* at the end, under the word *Loadstone* occurs the following passage:

"Another piece of Curiosity I saw in the Hands of Sir *William Persal* (since Deceased also) *viz.*, a *Terrella* or *Load-stone*, of little more than *6 Inches Diameter*, turned into a *Globular Form*, and all the *Imaginery Lines* of our *Terrestrial Globe*, exactly drawn upon it: *viz.* the *Artick* and *Antartick Circles*, the *two Tropicks*, the *two Colures*, the *Zodiack* and *Meridian*; and these *Lines*, and the several *Countryes*, artificially *Painted* on it, and all of them with their true *Distances*, from the two *Polar Points*, and to find the truth of those *Points*, he took two *little pieces* of a *Needle*, each of about *half an Inch in length*, {24}
and those he laid on the *Meridian line*, and then with *Brass Compasses*, moved one of them towards the *Artick*, which as it was moved, still raised it self at one end higher and higher, keeping the other end fixt to the *Terrella*; and when it had compleated it Journy to the very *Artick Points*, it stood upright upon that *Point*; then he moved the other piece of *Needle* to the *Antartick Point*, which had its *Elevations* like the other, and when it came to the *Point*, it fixt it self upon that *Point*, and stood *upright*, and then taking the *Terrella* in my Hand, I could perfectly see that the two *pieces* of *Needles* stood so exactly one against the other, as if it had been one intire *long Needle* put through the *Terrella*, which made me give credit to those who held, That there is an *Astral Influence* that *darts* it self through the *Globe* of *Earth* from *North* to *South* (and is as the *Axel-Tree* to the *Wheel*, and so called the *Axis* of the *World*) about which the *Globe* of the *Earth* is turned, by an *Astral Power*, so as what I thought *imaginary*, by this *Demonstration*, I found *real*."

[63] **Page 13, line 20.** Page 13, line 22. The editions of 1628 and 1633 give a different woodcut from this: they show the terrella lined with meridians, equator, and parallels of latitude: and they give the compass needle, at the top, *pointing in the wrong direction*.

[64] **Page 14, line 3.** Page 14, line 3. The Berlin "facsimile" reprint omits the asterisk here.

[65] **Page 14, line 5.** Page 14, line 6. *erectus* altered in ink in the folio to *erecta*. But *erectus* is preserved in editions 1628 and 1633. In Cap. IIII., on p. **14**, both these Stettin editions insert an additional cut representing the terrella A placed in a tub or vessel B floating on water.

[66] **Page 14, line 34.** Page 14, line 39. *variatione quadã.* The whole of Book IIII. is devoted to a discussion of the variation of the compass.

[67] **Page 16, line 28.** Page 16, line 34. *aquæ.*—This curious use of the dative occurs

also on p. **222**, line **8**.

[68] **Page 17, line 1.** Page 17, line 1. *videbis.*—The reading *vibebis* of the 1633 edition is an error.

[69] **Page 18, line 24.** Page 18, line 27. *Theamedem.*—For the myth about the alleged *Theamedes*, or repelling magnet, see Cardan, *De Subtilitate* (folio ed., 1550, lib. vii., p. 186).

Pliny's account, in the English version of 1601 (p. 587), runs:

"To conclude, there is another mountaine in the same Æthyopia, and not farre from the said Zimiris, which breedeth the stone Theamedes that will abide no yron, but rejecteth and driveth the same from it."

Martin Cortes, in his *Arte de Nauegar* (Seville, 1556), wrote:

"And true it is that Tanxeades writeth, that in Ethiope is found another kinde of this stone, that putteth yron from it" (Eden's translation, London, 1609).

[70] **Page 21, line 24.** Page 21, line 25. *Hic segetes, &c.*—The English version of these lines from Vergil's *Georgics*, Book I., is by the late Mr. R. D. Blackmore.

[71] **Page 22, line 18.** Page 22, line 19. *quale*, altered in ink in the folio text to *qualis*. The editions of 1628 and 1633 both read *qualis*.

[72] **Page 22, line 19.** Page 22, line 20. *rubrica fabrili*: in English *ruddle* or *reddle*. See "Sir" John Hill, *A General Natural History*, 1748, p. 47. In the *De Re Metallica* of Entzelt (Encelius), Frankfurt, 1551, p. 134, is a paragraph headed *De Rubrica Fabrili*, as follows: "Rubrica fabrilis duplex est. à Germanis añt utraque dicitur rottel, röttelstein, wie die {25}
zimmerleüt vnd steynmetzen brauchen. à Græcis μίλτος τεκτονική. Est enim alia nativa, alia factitia. Natiua à Germanis propriè dicitur berckrottel. haec apud nos est fossilis.... Porro factitia est rubrica fabrilis, à Germanis braunrottel, quæ fit ex ochra usta, ut Theophrastus et Dioscorides testantur."

[73] **Page 22, line 19.** Page 22, line 20. *In Sussexia Angliæ.*—In Camden's *Britannia* (1580) we read concerning the iron industry in the villages in Sussex: "They are full of iron mines in sundry places, where, for the making and founding thereof, there be furnaces on every side; and a huge deal of wood is yearly burnt. The heavy forge-hammers, worked by water-power, stored in hammer-ponds, ceaselessly beating upon the iron, fill the neighbourhood round about, day and night, with continual noise."

[74] **Page 23, line 1.** Page 22, line 44. *in libro Aristotelis de admirandis narrationibus.*—The reference is to the work usually known as the *De Mirabilibus Auscultationibus*, Cap. XLVIII.: "Fertur autem peculiarissima generatio esse ferri Chalybici Amisenique, ut quod ex sabulo quod a fluviis defertur, ut perhibent certe, conflatur. Alii simpliciter lotum in fornace excoqui, alii vero, quod ex lotura subsedit, frequentius lotum comburi tradunt adjecto simul et pyrimacho dicto lapide, qui in ista regio plurimus reperiri fertur." (Ed. Didot, vol. ii., p. 87.) According to Georgius Agricola, the stone pyrimachus is simply iron pyrites.

[75] **Page 23, line 22.** Page 23, line 23. *vt in Italia Comi*, &c.—This is mostly taken from Pliny. Compare the following passage from Philemon Holland's translation (1601), p. 514:

"But the most varietie of yron commeth by the meanes of the water, wherein the yron red-hot is eftsoones dipped and quenched for to be hardened. And verely, water only which in some place is better, in other worse, is that which hath ennobled many places for the excellent yron that commeth from them, as namely, Bilbilis in Spaine, and Tarassio, Comus also in Italie; for none of these places have any yron mines of their owne, and yet there is no talke but of the yron and steele that commeth from thence."

Bilbilis is Bambola, and Tariassona the Tarazona of modern Spain.

[76] **Page 24, line 28.** Page 24, line 27. *Quare vani sunt illi Chemici.*—Gilbert had no faith in the alchemists. On pp. **19** and **21** he had poked fun at them for declaring the metals to be constituted of sulphur and quicksilver, and for pronouncing the fixed earth in iron to be sulphur. On p. **20** he had denied their proposition that the differences between silver, gold, and copper could arise from proportions of their constituent materials; and he likewise denounced unsparingly the supposed relation between the seven metals and the seven planets. He now denounces the vain dreams of turning all metals into gold, and all stones into diamonds. Later he rejects as absurd the magnetic curing of wounds. His detachment from the pseudo-science of his age was unique if not complete.

[77] **Page 25, line 15.** Page 25, line 16. *Petro-coriis, & Cabis Biturgibus.*—The Petro-corii were a tribe in the neighbourhood of Perigord; the Cubi Biturges another in that of Bourges.

[78] **Page 25, line 21.** Page 25, line 23. Pliny's account, as translated by P. Holland (ed. 1601, p. 515), runs thus:

"Of all mines that be, the veine of this mettall is largest, and spreadeth it selfe into most lengths every way: as we may see in that part of Biscay that coasteth along the sea, and upon which the Ocean beateth: where there is a craggie mountaine very steep and high, {26} which standeth all upon a mine or veine of yron. A wonderfull thing, and in manner incredible, howbeit, most true, according as I have shewed already in my Cosmographie, as touching the circuit of the Ocean."

[79] **Page 26, Line 15.** Page 26, line 12. *quas Clampas nostri vocant.*—The name *clamp* for the natural kiln formed by heaping up the bricks, with ventilating spaces and fuel within the heap, is still current.

[80] **Page 26, line 39.** Page 26, line 38. *Pluebat in Taurinis ferrum.*—The occurrence is narrated by Scaliger, *De Subtilitate*, Exercitat. cccxxiii.:

"Sed falsò lapidis pluviam creas tu ex pulvere hausto à nubibus, atque in lapidem condensato. At ferrum, quod pluit in Taurinis, cuius frustum apud nos extat, qua ex fodina sustulit nubes? Tribus circiter annis antè, quàm ab Rege provincia illa recepta esset, pluit ferro multis in locis, sed raris" (p. 434, Editio Lutetiæ, 1557).

"During the latter ages of the Roman Empire the *city* of Augusta Taurinorum seems to have been commonly known (as was the case in many instances in Transalpine Gaul) by the name of the tribe to which it belonged, and is called simply Taurini in the Itineraries, as well as by other writers, hence its modern name of Torino or Turin" (Smith's *Dictionary of Greek and Roman Geographies*, p. 1113).

There exists a considerable literature respecting falls of meteors and of meteoric iron. Livy, Plutarch, and Pliny all record examples. See also *Remarks concerning stones said to have fallen from the clouds*, by Edward King (London, 1796); Chladni, *Ueber den Ursprung der von Pallas gefundenen und anderer ihr ähnlicher Eisenmassen* (Riga, 1794); *Philosophical Transactions*, vol. lxxviii., pp. 37 and 183; vol. lxxxv., p. 103; vol. xcii., p. 174; Humboldt's *Cosmos*, vol. i. (p. 97 of London edition, 1860); C. Rammelsberg, *Die chemische Natur der Meteoriten* (Berlin, 1879); Maskelyne, *Some lecture-notes on Meteorites* printed in *Nature*, vol. xii., pp. 485, 504, and 520, 1875. Maskelyne denominates as *siderites* those meteorites which consist chiefly of iron. They usually contain from 80 to 95 per cent. of iron, often alloyed with nickel. This meteoric iron is sometimes so pure that it can at once be forged by the smith. An admirable summary of the whole subject is to be found in L. Fletcher's *An Introduction to the study of Meteorites*, publisht by the British Museum (Nat. Hist.), London, 1896.

[81] **Page 27, line 3.** Page 26, line 41. *vt Cardanus ... scribit.*—The passage runs:

"Vidimus anno MDX cum cecidisset è cœlo lapides circiter MCC in agrum fluvio Abduæ conterminum, ex his unum CXX pondo, alium sexaginta delati fuerunt ad reges Gallorũ satrapes, plurimi: colos ferrugineus, durities eximia, odor sulphureus" (Cardan, *De Rerum Varietate*, lib. xiiii., cap. lxxii.; Basil., 1557, p. 545).

[82] **Page 27, line 9.** Page 27, line 2. *aut stannum, aut plumbum album.* Although most authorities agree in translating *plumbum album* or *plumbum candidum* as "tin" (which is unquestionably the meaning in such examples as Pliny's *Nat. Hist.*, xxxiv. 347, and iv. 16; or Strabo, iii. 147), nevertheless it is certain that here *plumbum album* is not given as a synonym of *stannum* and therefore is not *tin*. That Gilbert meant either spelter or pewter is pretty certain. He based his metallic terms mainly upon Encelius (Christoph Entzelt) whose *De Re Metallica* was published at Frankfurt in 1551. From this work are taken the following passages: {27}

p. 61. *De Plumbo candido.* Cap. XXXI.

"Veluti plumbum nigrũ uocatur à Germanis blei simpliciter, od' schwartzblei: ita plumbũ candidũ ab his uocatur weissblei, od' ziñ. Impropriè autem plumbum hoc nostrum candidum ziñ, stannum dicitur. Et non sunt idem, ut hactenus voluerunt, stannum et plumbum candidum, unser ziñ. Aliud est stannum, de quo mox agemus: et aliud plumbum candidum nostrum, unser ziñ, quod nigro plumbo quasi est quiddã purius et perfectius...."

p. 62. *De Stanno.* Cap. XXXII.

"In præcedenti capite indicauimus aliud esse stannum, aliud esse plumbũ candidũ. Illa ergo definitio plumbi candidi, dess zinnes, etiã apud chimistas nõ de stanno, sed de plumbo candido (ut mihi uidetur) intelligenda est, cum dicunt: Stannum (es soll heyssen plumbum candidum) est metallicum album, non purum, lividum...."

p. 63. "Sic uides stannum, secundum Serapionem, metallicum esse quod reperitur in sua propria uena, ut forsitan apud nos bisemutũ: ecõtra nostrũ candidũ plumbũ, est Plinij candidũ plumbũ, das zin, quod cõflatur ut plumbum nigrum, ex pyrite, galena, et lapillis nigris. Deinde uides stannum Plinio esse quiddã de plumbo nigro, nempe primum fluorem plumbi nigri, als wann man vnser bley ertz schmeltzet, das erst das do fleüsset, zwäre Plinio stannum. Et hoc docet Plinius adulterari plũbo candido, mit vnserm zinn, vnd wann du ihm recht nachdenckest, daruon die kannen gemacht werden, das man halbwerck heist.... O ir losen vngelerten, vnckenbrenner. Stannum proculdubio Arabis metallum est preciosius nostro candido plumbo: sicuti apud nos bisemuthum quiddam plumbo

preciosius."

[83] **Page 27, line 21.** Page 27, line 17. *venas ... venis.*—It is impossible to give in English this play on words between veins of ore and veins of the animal body.

[84] **Page 28, line 23.** Page 28, line 20. *quem nos verticitatem dicimus.*—See the notes on Gilbert's glossary, *ante*. The word verticity remained in the language. On p. 140 of Joseph Glanvill's *Vanity of Dogmatizing* (Lond., 1661) we read: "We believe the *verticity* of the *Needle*, without a Certificate from the *dayes* of *old*."

[85] **Page 29, line 15.** Page 29, line 16. *Nos verò diligentiùs omnia experientes.*—The method of carefully trying everything, instead of accepting statements on authority, is characteristic of Gilbert's work. The large asterisks affixed to Chapters IX. X. XI. XII. and XIII. of Book I. indicate that Gilbert considered them to announce important original magnetical discoveries. The electrical discoveries of Book II., Chapter II., are similarly distinguished. A rich crop of new magnetical experiments, marked with marginal asterisks, large and small, is to be found in Book II., from Chapter XV. to Chapter XXXIV.; while a third series of experimental magnetical discoveries extends throughout Book III.

[86] **Page 31, line 30.** Page 31, line 25. *verticem.*—The context and the heading of the Chapter appear to require *verticitatem*. All editions, however, read *verticem*.

[87] **Page 32, line 12.** Page 32, line 9. *Gartias ab horto.*—The passage from Gartias ab Horto runs as follows in the Italian edition of 1616, *Dell' Historia dei Semplici Aromati....* di Don Garzia dall' Horto, Medico Portughese, ... Venezia MDCXVI., p. 208.

"Nè meno è questa pietra velenosa, si come molti hanno tenuto; imperoche le genti di queste bande dicono che la Calamita presa per bocca, però in poca quantità, conserva la {28}
gioventù. La onde si racconta, che il Re di Zeilan il vecchio' s'haveva fatto fare tutti i vasi, dove si cocevano le vivãde per lui, di Calamita. Et questo lo disse à me colui proprio, che fu à questo officio destinato."

[88] **Page 32, line 29.** Page 32, line 29. *Plutarchus & C. Ptolemæus.*—The garlick myth has already been referred to in the note to p. **1**. The originals are Plutarch, *Quæstiones Platonicæ*, lib. vii., cap. 7, § 1; C. Ptolemæus, *Opus Quadripartitum,* bk. i., cap. 3. The English translation of the latter, by Whalley (London, 1701), p. 10, runs: "For if the *Loadstone* be *Rubbed* with *Garlick*, the *Iron will not be drawn by it*."

[89] **Page 32, line 32.** Page 32, line 33. *Medici nonnulli.*—This is apparently a reference to the followers of Rhazes and Paracelsus. The argument of Gilbert as to the inefficacy of powdered loadstones is reproduced more fully by William Barlowe in his *Magneticall Aduertisements* (1616, p. 7), as follows:

"It is the goodnesse of the *Loadstone* ioyned with a fit forme that will shew great force. For as a very good forme with base substance can doe but very litle, so the substance of the *Loadstone* bee it neuer so excellent, except it haue some conuenient forme, is not auaileable. For example, an excellent *loadstone* of a pound waight and of a good fashion, being vsed artificially, may take vp foure pounds of Iron; beate it into small pouder, and it shall bee of no force to take vp one ounce of Iron; yea I am very well assured that halfe an ounce of a Loadstone of good fashion, and of like vertue will take vp more then that pound will doe being beaten into powder. Whence (to adde this by the way) it appeareth manifestly, that it is a great error of those Physitions and Surgeons, which to remedy ruptures, doe prescribe vnto their Patients to take the pouder of a *Loadstone* inwardly, and the small filing of iron mingled in some plaister outwardly: supposing that herein the *magneticall* drawing should doe great wonders."

[90] **Page 33, line 11.** Page 33, line 8. *Nicolaus in emplastrum divinum....*—Nicolaus Myrepsus is also known as Præpositas. In his *Liber de compositione medicamentorum* (Ingoldstat, 1541, 4to) are numerous recipes containing loadstone: for example, Recipe No. 246, called "esdra magna," is a medicine given for inflammation of the stomach and for strangury, compounded of some forty materials including "litho demonis" and "lapis magnetis." The *emplastrum divinum* does not, however, appear to contain loadstone. In the English tractate, *Præpositas his Practise, a worke ... for the better preservation of the Health of Man. Wherein are ... approved Medicines, Receiptes and Ointmentes. Translated out of Latin in to English by* L. M. (London, 1588, 4to), we read on p. 35, "An Emplaister of D. N. [Doctor Nicolaus] which the Pothecaries call Divinum." This contains litharge, bdellium, and "green brasse," but no loadstone.

Luis de Oviedo in his treatise *Methodo de la Coleccion y reposicion de las Medicinas simples*, edited by Gregorio Gonçalez, Boticario (Madrid, 1622), gives (p. 502) the following: "Emplasto de la madre. *Recibe*: Nuezes moscadas, clauos, cinamono, artemisia, piedraimon. De cada uno dos onças.... Entre otras differencias que ay de piedraiman se hallan dos. Vna que por la parte que mira al Septentrion, atrae el hierro, por lo quel se llama magnes ferrugineus. Y otra que atrae la carne, a la qual llaman magnes creaginus."

An "Emplastrum sticticum" containing amber, mummy, loadstone, hæmatite, and twenty {29}
other ingredients, and declared to be "vulnerum ulcerumque telo inflictorum sticticum emplastrum præstantissimum," is described on p. 267 of the *Basilica chimica* of Oswaldus Crollius (Frankfurt, 1612).

[91] **Page 33, line 12.** Page 33, line 9. *Augustani ... in emplastrum nigrum*....—Amongst the physicians of the Augsburg school the most celebrated were Adolphus Occo, Ambrosio Jung, and Gereone Seyler. This particular reference is to the *Pharmacopœia Augustana ... a Collegio Medico recognita*, published at Augsburg, and which ran through many editions. The recipe for the "*emplastrum nigrum vulgo Stichpflaster*" will be found on p. 182 of the seventh edition (1621-2). The recipe begins with oil of roses, colophony, wax, and includes some twenty-two ingredients, amongst them mummy, dried earthworms, and two ounces *lapidis magnetis præparati*. The recipe concludes: "Fiat Emplastrum secundùm artem. Perquàm efficax ad recentia vulnera et puncturas, vndè denominationem habet." The volume is a handsome folio not unlike Gilbert's own book, and bears at the end of the prefatory address *ad Lectorem* identically the same *cul de lampe* as is found on p. **44** of *De Magnete*.

The contradictions as to the alleged medicinal virtues of loadstone are well illustrated by Galen, who in his *De facultatibus* says that loadstone is like hæmatite, which is astringent, while in his *De simplici medicina* he says it is purgative.

[92] **Page 33, line 14.** Page 33, line 12. *Paracelsus in fodicationum emplastrum.*—Paracelsus's recipe for a plaster against stab-wounds is to be found in *Wundt vund Leibartznei* ... D. Theoph. Paracelsus (Frankf., 1555, pp. 63-67).

[93] **Page 33, line 17.** Page 33, line 15. *Ferri vis medicinalis.*—This chapter on the medicinal virtues of iron is a summary of the views held down to that time. Those curious to pursue the subject should consult Waring's *Bibliotheca Therapeutica* (London, 1878). Nor should they miss the rare black-letter quarto by Dr. Nicholas Monardus, of Seville, *Joyfull Newes out of the New-found Worlde*, translated by John Frampton (London, 1596), in which are recited the opinions of Galen, Rhazes, Avicenna, and others, on the medicinal properties of iron. In addition to the views of the Arabic authors, against whom his arguments are directed, Gilbert discusses those of Joannes Manardus, Curtius, and Fallopius. The treatise of Manardus, *Epistolarum medicinalium libri viginti* (Basil., 1549), is a *résumé* of the works of Galen and the Arabic physicians, but gives little respecting iron. Curtius (Nicolaus) was the author of a book, *Libellus de medicamentis præparatibus et purgantibus* (Giessæ Cattorum, 1614). The works of Fallopius are *De Simplicibus Medicamentis purgentibus tractatus* (Venet., 1566, 4to), and *Tractatus de Compositione Medicamentorum* (Venet., 1570, 4to).

[94] **Page 34, line 7.** Page 34, line 3. *quorundã Arabum opiniones.*—The Arabian authorities referred to here or elsewhere by Gilbert are:

Albategnius (otherwise known as Machometes Aractensis), Muhammad Ibn Jābir, *Al-Battānī*.

Avicenna (otherwise Abohali). Abou-'Ali al-'Hoséin ben-'Abd-Allah Ibn-Sinâ, or, shortly, *Ibn Sîna.*

Averroes. Muhammad Ibn Ahmed Ibn-Roschd, *Abou Al-Walíd.*

Geber. Abū Mūsā Jābir Ibn Haiyān, *Al-Tarsūsi.*

Hali Abas. 'Alí Ibn Al-'Abbás, *Al Majúsi*. {30}

Rhazes, or *Rasis*. Muhammad Ibn Zakarīyā.

Serapio. Yuhanná Ibn Sarapion.

Thebit Ben-Kora (otherwise Thabit Ibn Corrah). Abū Thabit Ibn Kurrah, *Al Harrani.*

[95] **Page 34, line 38.**: Page 34, line 40. *electuarium de scoria ferri descriptum à Raze.*—Rhazes or Rasis, whose Arabic name was Muhammad Ibn Zakarīyā, wrote *De Simplicibus, ad Almansorem.* In Chap. 63 of this work he gives a recipe for a stomachic, which includes fennel, anise, origanum, black pepper, cinammon, ginger, and iron slag. In the splendid folio work of Rhazes publisht at Venice in 1542, with the title *Habes candide lector Continẽtem Rasis*, Libri ultimi, cap. 295, under the heading *De Ferro,* are set forth the virtues of iron slag: "Virtus scorie est sicut virtus scorie [a]eris sed debilior in purgãdo: et erugo ferri est stiptica: et cũ superpositur retinet fluxus menstruorũ.... Ait Paulus: aqua in qua extinguitur ferrũ calens.... Dico: certificatus sum experientia q̃ valet contra emorryodas diabetem et fluxum menstruorum."

[96] **Page 35, line 16.**: Page 35, line 13. *Paulus.*—This is not Fra Paolo Sarpi, nor Marco Polo, nor Paulus Jovius the historian, nor Paulus Nicolettus Venetus, but Paulus Aeginæ.

[97] **Page 35, line 29.**: Page 35, line 28. *Sed malè Avicenna.*—The advice of Avicenna to administer a draught containing powdered loadstone, reads as follows in the Giunta edition (Venice, 1608):

Lib. ii., cap. 470, p. 356. "Magnes quid est? Est lapis qui attrahit ferrum, quum ergo aduritur, fit hæmatites, & virtus ejus est sicut virtus illius.... Datur in potu [ad bibitionem limaturæ ferri, quum retinetur in ventre scoria ferri. Ipse enim extrahit] ipsam, & associatur ei apud exitum. Et dicitur, quando in potu sumuntur ex eo tres anulusat cum

mellicrato, educit solutione humorem grossum malum."

The passage is identical with that in the Venetian edition of 1486, in both of which the liquid prescribed is mellicratus—mead. Gilbert says that the iron is to be given in juice of *mercurialis*. Here he only follows Matthiolus, who, in his *Commentaries on Dioscorides*, says (p. 998 of the Basil. edition of 1598): "Sed (vt idem Auicenna scribit) proprium hujusce ferrei pharmaci antidotum, est lapis magnes drachmæ pondere potus, ex mercurialis, vel betæ succo."

Serapio, in his *De Simplicibus Medicinis* (Brunfels' edition, Argentorati, 1531), p. 264, refers to Galen's prescription of iron scoriæ, and under the article *de lapide magnetis*, p. 260, quotes Dioscorides as follows: "Et uirtus huius lapidis est, ut quãdo dantur in potu duo onolosat ex eo cũ melicrato, laxat humores grossos."

The original passage in Dioscorides, *De Materia Medica,* ch. 147 (Spengel's edition of 1829) runs: "Τοῦ δὲ μαγνήτου λίθου ἄριστός ἐστιν ὁ τὸν σίδηρον εὐχερῶς ἕλκων, καὶ τὴν χρόαν κυανίζων, πυκνός τε κὰι οὐκ ἄγαν βαρύς. Δύναμιν δὲ ἔχει πάχους ἀγωγὸν διδόμενος μετὰ μελικράτου τριωβόλου βάρος· ἔνιοι δὲ τοῦτον καίοντες ἀντὶ αἱματίτου πιπράσκουσιν.."

In the Frankfurt edition of Dioscorides, translated by Ruellius (1543), the passage is:

"Magnes lapis optimus est, qui ferrum facile trahit, colore ad cœruleum uergente, densus, nec admodum gravis. Datur cum aqua mulsa, trium obolorum pondere, ut crassos humores eliciat. Sunt qui magnetem crematũ pro hæmatite vendant...."

In the *Scholia* of Joannes Lonicerus upon Dioscorides *In Dioscoridæ Anazarbei de re medica libros a Virgilio Marcello versos, Scholia nova, Ioanne Lonicero autore* (Marburgi, 1543, p. 77), occurs the following: {31}

"*De recremento ferri.* Cap. XLIX.

"Σκωρία σιδήρου. scoria vel recrementum ferri. Quæ per ignem à ferro et cupro sordes separantur ac reijciuntur, et ab aliis metallis σκωρία uocantur. Omnis scoria, maxime uero ferri exiccat. Acerrimo aceto macerauit Galenus ferri scoriam, ac deinde excocto, pharmacum efficax confecit ad purulentas quæ multo tempore uexatæ erant, aures, admirando spectantium effectu. Ardenti scoria uel recrementum ἕλκυσμα, inquit Galenus."

See also the *Enarrationes eruditissimæ* of Amatus Lusitanus (Venet., 1597), pp. 482 and 507, upon iron and the loadstone.

[98] **Page 36, line 27.** Page 36, line 29. *eijcitur* for *ejicitur*.

[99] **Page 37, line 18.** Page 37, line 22. *ut Cardanus philosophatur.*—Cardan's nonsense about the magnet feeding on iron is to be found in *De Subtilitate*, lib. vii. (Basil., 1611, p. 381).

[100] **Page 38, line 4.** Page 38, line 7. *ferramenta ... in usum navigantium.*—Compare Marke Ridley's *A Short Treatise of Magneticall Bodies and Motions* (Lond., 1613), p. *a2* in the *Preface Magneticall,* where he speaks of the "iron-workes" used in building ships. The phraseology of Marke Ridley throws much light on the Latin terms used by Gilbert.

[101] **Page 38, line 36.** Page 38, line 42. *vruntur;* changed in ink to *vrantur* in the folio of 1600; but *uruntur* appears in the editions of 1628 and 1633.

[102] **Page 39, line 12.** Page 39, line 12. *virumque;* altered in ink to *virunque* in all copies of the folio edition of 1600.

[103] **Page 40, line 32.** Page 40, line 33. *ad tantos labores exantlandos.*—Pumping, as it was in mining before the invention of the steam engine, may best be realized by examining the woodcuts in the *De re metallica* of Georgius Agricola (Basil., Froben, 1556).

[104] **Page 40, line 34.** Page 40, line 36. *quingentas orgyas.*—Gilbert probably had in his mind the works of the Rorerbühel, in the district of Kitzbühl, which in the sixteenth century had reached the depth of 3,107 feet. See Humboldt's *Cosmos* (Lond., 1860, vol. i., p. 149).

[105] **Page 43, line 34.** Page 43, line 33. *glis.*—This word, here translated *grit*, does not appear to be classical Latin; it may mean *ooze or slime*.

[106] **Page 45, line 25.** Page 45, line 26. *Motus igitur ... quinque.* The five kinds of magnetic motions correspond in fact to the remaining sections of the book; as follows: *Coitio*, Book II.; *Directio*, Book III.; *Variatio*, Book IV.; *Declinatio*, Book V.; and *Revolutio*, Book VI.

[107] **Page 46, line 7.** Page 46, line 8. *Jofrancus Offusius.*—The reference is to the treatise *De divina astrorum faculitate* of Johannes Franciscus Offusius (Paris, 1570).

[108] **Page 47, line 15.** Page 47, line 18. *Græci vocant* ἠλεκτρον, *quia ad se paleas*

trahit. In this discussion of the names given to amber, Gilbert apparently conceives ἠλεκτρον to be derived from the verb ἑλκεῖν; which is manifestly a doubtful etymology. There has been much discussion amongst philologists as to the derivation of ἠλέκτρον or ἤλεκτρον, and its possible connection with the word ἠλέκτωρ. This discussion has been somewhat obscured by the circumstance that the Greek authors unquestionably used ἤλεκτρον (and the Latins their word *electrum*) in two different significations, some of them using these words to mean amber, others to mean a shining metal, apparently of {32}
having qualities between those of gold and silver, and probably some sort of alloy. Schweigger, *Ueber das Elektron der Alten* (Greifswald, 1848), has argued that this metal was indeed no other than platinum: but his argument partakes too much of special pleading. Those who desire to follow the question of the derivation of ἤλεκτρον may consult the following authorities: J. M. Gessner, *De Electro Veterum* (Commentt. Soc. Reg. Scientt. Goetting., vol. iii., p. 67, 1753); Delaunay, *Mineralogie der Alten*, Part II., p. 125; Buttmann, *Mythologus* (Appendix I., *Ueber das Elektron*), Vol. II., p. 355, in which he adopts Gilbert's derivation from ἔλκειν; Beckmann, *Ursprung und Bedeutung des Bernsteinnamens Elektron* (Braunsberg, 1859); Th. Henri Martin, *Du Succin, de ses noms divers et de ses variétés suivant les anciens* (Mémoires de l'Académie des Inscriptions et Belles-lettres, Tome VI., 1re série, 1re partie, 1860); Martinus Scheins, *De Electro Veterum Metallico* (Inaugural dissertation, Berlin, 1871); F. A. Paley, *Gold Worship in relation to Sun Worship* (Contemporary Review, August, 1884). See also Curtius, *Grundzüge der griechischen Etymologie*, pp. 656-659. The net result of the disputations of scholars appears to be that ἠλέκτωρ (he who shines) is a masculine form to which there corresponds the neuter form ἤλεκτρον (that which shines). Stephanus admits the accentuation used by Gilbert, ἠλέκτρον, to be justified from the *Timæus* of Plato; see Note to p. **61**.

[109] **Page 47, line 16.** Page 47, line 19. ἄρπαξ dicitur, & χρυσοφόρον.—With respect to the other names given to amber, M. Th. Henri Martin has written (see previous note) so admirable an account of them that it is impossible to better it. It is therefore given here entire, as follows:

> "Le succin a reçu chez les anciens des noms très-divers. Sans parler du nom de λυγκούριον, lyncurium, qui peut-être ne lui appartient pas, comme nous le montrerons plus loin, il s'est nommé chez les Grecs le plus souvent ἤλεκτρον au neutre,[1] mais aussi ἤλεκτρος au masculin[2] et même au féminin,[3] χρυσήλεκτρος,[4] χρυσόφορος[5] et peut-être, comme nous l'avons vu, χαλκολίθανον; plus tard σούχιον[6] ou σουχίνος[7], et ἠλεκτριανὸς λίθος;[8] plus tard encore βερενίκη, βερονίκη ou βερνίκη;[9] il s'est nommé ἄρπαξ chez les Grecs établis en Syrie;[10] chez les Latins *succinum*, *electrum*, et deux variétés, *chryselectrum* et *sualiternicum* ou {33}
> *subalternicum*;[11] chez les Germains, *Gless*;[12] chez les Scythes, *sacrium*;[13] chez les Egyptiens, *sacal*;[14] chez les Arabes, *karabé*[15] ou *kahraba*;[16] en persan, *káruba*.[17] Ce mot, qui appartient bien à la langue persane, y signifie *attirant la paille*, et par conséquent exprime l'attraction électrique, de même que le mot ἄρπαξ des Grecs de Syrie. En outre, le nom de *haur roumi* (*peuplier romain*) était donné par les Arabes, non-seulement à l'arbre dont ils croyaient que le succin était la gomme, mais au succin lui-même. *Haur roumi*, transformé en *aurum* par les traducteurs latins des auteurs arabes, et consondu mal à propos avec *ambar* ou *ambrum*, nom arabe latinisé de l'ambre gris, a produit le nom moderne d'*ambre*, nom commun à l'*ambre jaune* ou succin, qui est une résine fossile, et à l'*ambre gris*, concrétion odorante qui se forme dans les intestines des cachalots. On ne peut dire avec certitude si le nom de basse grécité βερνίκη est la source ou le dérivé de *Bern*, radical du nom allemand du succin (*Bernstein*). Quoi qu'il en soit, le mot βερνίκη a produit *vernix*, nom d'une gomme dans la basse latinité, d'où nous avons fait *vernis*.[18]"

[1] Voyez Hérodote, III., 115; Platon, *Timée*, p. 80 c; Aristote, *Météor.*, IV., 10; Théophraste, *Hist. des plantes*, IX., 18 (19), § 2; *Des pierres*, § 28 et 29; Diodore de Sic., V., 23; Strabon, IV., 6, no 2, p. 202 (Casaubon); Dioscoride, *Mat. méd.*, I., 110; Plutarque, *Questions de table*, II., 7, § 1; *Questions platoniques*, VII., 1 et 7; Lucien, *Du succin et des cygnes*; le même, *De Pastrologie*, § 19; S. Clément, *Strom.* II., p. 370 (Paris, 1641, in-fol.); Alexandre d'Aphr., *Quest. phys. et mor.*, II., 23; Olympiodore, *Météor.*, I., 8, fol. 16, t. I., p. 197 (Ideler) et l'abréviateur d'Etienne de Byzance au mot Ηλεκτρίδες.

[2] Voyez Sophocle, *Antigone*, v. 1038, et dans Eustathe, sur l'*Iliade*, II., 865; Elien, *Nat. des animaux*, IV. 46; Quintus de Smyrne, V., 623; Eustathe, sur la *Périégèse* de Denys, p. 142 (Bernhardy), et sur l'*Odyssée*, IV., 73; et Suidas au mot ὐάλη.

[3] Voyez Alexandre, *Problèmes*, sect. 1, procem., p. 4 (Ideler); Eustathe, sur l'*Odyssée*, IV., 73, et Tzetzès, *Chiliade* VI., 650.

[4] Voyez Psellus, *Des pierres*, p. 36 (Bernard et Maussac).

[5] Voyez Dioscoride, *Mat. méd.*, I., 110.

[6] Voyez S. Clément, *Strom.*, II., p. 370 (Paris, 1641, in-fol.). Il paraît distinguer l'un de l'autre τὸ σούχιον et τὸ ἤλεκτρον, probablement parce qu'il attribue à tort au métal ἤλεκτρον la propriété

attractive du succin.

[7] Voyez le faux Zoroastre, dans les *Géoponiques*, XV., 1, § 29.

[8] Voyez le faux Zoroastre, au même endroit.

[9] Voyez Eustathe, sur l'*Odyssée*, IV., 73; Tzetzès, *Chil.* VI., 650; Nicolas Myrepse, *Antidotes*, ch. 327, et l'Etymol. Gud. au mot ἤλεκτρον. Comparez Saumaise, Exert. plin., p. 778.

[10] Voyez Pline, XXXVII., 2, s. 11, n° 37.

[11] Voyez Pline, XXXVII., 2, s. 11-13, et Tacite, *Germanie*, ch. 45. La forme *sualiternicum*, dans Pline (s. 11, n° 33), est donnée par le manuscrit de Bamberg et par M. Sillig (t. V., p. 390), au lieu de la forme *subalternicum* des éditions antérieures.

[12] Voyez Tacite et Pline, *ll. cc.*

[13] Voyez Pline, XXXVII., 2, s. 11, n° 40, Comp. J. Grimm, *Gesch. der deutsch. Sprache*, Kap. x., p. 233 (Leipzig, 1848, in-8).

[14] Pline, *l. c.*

[15] Voyez Saumaise, *De homon. hyles iatricæ*, c. 101, p. 162 (1689, in-fol.).

[16] Voyez Sprengel, sur Dioscoride, t. II., pp. 390-391.

[17] Voyez M. de Sacy, cité par Buttmann, *Mythologus*, t. II., pp. 362-363.

[18] Voyez Saumaise, *Ex. plin.*, p. 778. Il n'est pas probable que le mot βερνίκη ou βερενίκη nom du succin dans la grécité du moyen âge, soit lié étymologiquement avec le nom propre βερενίκη, qui vient de l'adjectif macédonien βερένικος pour φερένικος.

[110] **Page 47, line 17.** Page 47, line 20. *Mauri vero Carabem appellant, quià solebant in sacrificijs, & deorum cultu ipsum libare. Carab enim significat offerre Arabicè; ita Carabe, res oblata; aut rapiens paleas, vt Scaliger ex Abohali citat, ex linguâ Arabicâ, vel Persicâ.*—The printed text, line **18**, has "Non rapiens paleas," but in all copies of the folio of 1600, the "Non" has been altered in ink into "aut," possibly by Gilbert's own hand. Nevertheless the editions of 1628 and 1633 both read "Non." There appears to be no doubt that the origin of the word *Carabe*, or *Karabe*, as assigned by Scaliger, is substantially correct. As shown in the preceding note, Martin adopted this view. If any doubt should remain it will be removed by the following notes which are due to Mr. A. Houtum Schindler (member of the Institution of Electrical Engineers), of Terahan.

Reference is made to the magnetic and electric properties of stones in three early Persian lapidaries. There are three stones only mentioned, amber, loadstone, and garnet. The electric property of the diamond is not mentioned. The following extracts are from the *Tansûk nâmah*, by Nasîr ed dîn Tûsi, A.D. 1260. The two other treatises give the first extracts in the same words.

"*Kâhrubâ*, also *Kahrabâ* [Amber],

"Is yellow and transparent, and has its name from the property, which it possesses, of attracting small, dry pieces of straw or grass, after it has been rubbed with cloth and become warm. [Note. In Persian, Kâh = straw; rubâ = the robber, hence Kâhrubâ = the straw-robber.] Some consider it a mineral, and say that it is found in the Mediterranean and Caspian seas, floating on the surface, but this is not correct. The truth is that Kâhrubâ is the gum of a tree, called jôz i rûmî [*i.e.*, roman nut; walnut?], and that most of {34}
it is brought from Rûm [here the Eastern Rome] and from the confines of Sclavonia and Russia. On account of its bright colour and transparency it is made into beads, rings, belt-buckles, &c. ... &c.

"The properties of attraction and repulsion are possessed by other substances than loadstone, for instance, by amber and bîjâdah,[1] which attract straws, feathers, etc., and of many other bodies, it can be said that they possess the power of attraction. There is also a stone which attracts gold; it has a pure yellow colour. There is also a stone which attracts silver from distances of three or two yards. There are also the stone which attracts tin, very hard, and smelling like asafœtida, the stone attracting hair, the stone attracting meat, etc., but, latterly, no one has seen these stones: no proof, however, that they do not exist."

Avicenna (Ibn Sinâ) gives the following under the heading of *Karabe* (see *Canona Medicinæ*, Giunta edition, Venet., 1608, lib. ii., cap. 371, p. 336):

"Karabe quid est? Gumma sicut sandaraca, tendens ad citrinitatem, & albedinem, & peruietatem, & quandoque declinat ad rubedinem, quæ attrahit paleas, & [fracturas] plantarum ad se, & propter hoc nominatur Karabe, scilicet rapiens paleas, persicè.... Karabe confert tremori cordis, quum bibitur ex eo medietas aurei cum aqua frigida, &

prohibet sputum sanguinis valde.... Retinet vomitum, & prohibet materias malas a stomacho, & cum mastiche confortat stomachum.... Retinet fluxum sanguinis ex matrice, & ano, & fluxum ventris, & confert tenasmoni."

Scaliger in *De Subtilitate*, *Exercitatio* ciii., § **12**, the passage referred to by Gilbert says: "Succinum apud Arabas uocatur, Carabe: quod princeps Aboali, rapiens paleas, interpretatur" (p. 163 *bis*, editio Lutetiæ, 1557).

[1] *Bîjâdah* is classified by Muhammad B. Mansûr (A.D. 1470) and by Ibn al Mubârak (A.D. 1520) under "stones resembling ruby"; the Tansûk nâmah describes it in a separate chapter. From the description it can be identified with the almandine garnet, and the method of cutting this stone *en cabochon*, with hollow back in order to display its colour better is specially mentioned. The Tansûk nâmah only incidentally refers to the electric property of the *bîjâdah* in the chapter on loadstone, but the other two treatises specially refer to it in their description of the stone. The one has: "*Bîjâdah* if rubbed until warm, attracts straws and other light bodies just as amber does"; the other: "*Bîjâdah*, if rubbed on the hair of the head, or on the beard, attracts straws." Surûri, the lexicographer, who compiled a dictionary in 1599, considers the *bîjâdah* "a red ruby which possesses the property of attraction." Other dictionaries do not mention the attractive property, but some authors confound the stone with amber, calling it *Kâbrubâ*, the straw-robber. The *bîjâdah* is not rubellite (red tourmaline) for it is described in the lapidaries as common, whereas rubellite (from Ceylon) has always been rare, and was unknown in Persia in the thirteenth century.

[111] **Page 47, line 21.** Page 47, line 25. *Succinum seu succum.*—Dioscorides regarded amber as the inspissated juice of the poplar tree. From the Frankfurt edition of 1543 (*De Medicinali materia, etc.*) edited by Ruellius, we have, liber i., p. 53:

Populus. Cap. XCIII.

"... Lachrymam populorum commemorant quæ in Padum amnem defluat, durari, ac coire in succinum, quod electrum vocant, alii chrysophorum. id attritu jucundum odorem spirat, et aurum colore imitatur. tritum potumque stomachi ventrisque fluxiones sistit."

To this Ruellius adds the commentary:

"Succinum seu succina gutta à succo dicta, Græcis ἤλεκτρομ [sic], esse lachryma populi albæ, vel etiam nigræ quibusdam videtur, ab ejusdem arboris resina. Dioscoridi et Galeno dicta differens et πτερυγοφόρος, id est paleas trahens, quoque vocatur, quantum ei quoque Galenus tribuit li. 37, ca. 9. Succinum scribit à quibusdam pinei generis arboribus, ut gummi à cerasis excidere autumno, et largum mitti ex Germania septentrionali, et insulis maris Germanici. quod hodie nobis est compertissimum: ad hæc liquata igni valentiore, quia à frigido intensiore concrevit. pineam aperte olet, calidum primo gradu, siccum secundo, stomachum roborat, vomitum, nauseam arcet. cordis palpitationi prodest. pravorem humorum generationem prohibet. {35}

"Germani weiss und gelbaugstein et brēnstein.

"Galli ambra vocant: vulgo in corollis precariis frequens."

In the scholia of Johann Lonicer in his edition of Dioscorides, we find, lib. i., cap. xcviii., *De nigra Populo*:

"ἄιγειρος, populus nigra ... idem electrum vel succinum αἰγείρου lachrymam esse adseverat [Paulus], cui præter vires quæ ab Dioscoride recensentur, tribuit etiam vim sistendi sanguinis, si tusum in potu sumatur. Avicennæ Charabe, ut colligitur ex Joanne Jacobo Manlio, est electrum hoc Dioscoridis, attestatur Brunfelsius. Lucianus planè nullum electrum apud Eridanum seu Padum inveniri tradit, quandoquidem ne populus quidem illa ab nautis ei demonstrari potuerit. Plinius rusticas transpadanas ex electro monilia gestare adfirmat, quum à Venetis primum agnoscere didicissent adversus nimirum vitia gutturis et tonsillarum. Num sit purgamentum maris, vel lachryma populi, vel pinus, vel ex radiis occidentis solis nascatur, vel ex montibus Sudinorum profluat, incertum etiam Erasmus Stella relinquit. Sudinas tamen Borussiorum opes esse constat."

Matthiolus (in *P. A. Mattioli ... Opera quæ extant omnia, hoc est Commentarii in vi libros P. Dioscoridis de materia medica*, Frankfurt, 1596, p. 133) comments on the suggestion of Galen that amber came from the *Populus alba*, and also comments on the Arabic, Greek, and Latin names of amber.

The poplar-myth is commemorated by Addison (in *Italy*) in the lines:

> No interwoven reeds a garland made,
> To hide his brows within the vulgar shade;
> But poplar wreathes around his temples spread,
> And tears of amber trickled down his head.

Amber is, however, assuredly not derived from any poplar tree: it comes from a species of pine long ago extinct, called by Göppert the *pinites succinifer*.

Gilbert does not go into the medicinal uses, real or fancied, that have been ascribed to amber in almost as great variety as to loadstone. Pliny mentions some of these in his

Natural Historie (English version of 1601, p. 609):

"He [Callistratus] saith of this yellow Amber, that if it be worne about the necke in a collar, it cureth feavers, and healeth the diseases of the mouth, throat, and jawes: reduced into pouder and tempered with honey and oile of roses, it is soveraigne for the infirmities of the eares. Stamped together with the best Atticke honey, it maketh a singular eyesalve for to help a dim sight: pulverized, and the pouder thereof taken simply alone, or else drunke in water with Masticke, is soveraigne for the maladies of the stomacke."

Nicolaus Myrepsus (Recipe 951, *op. citat.*) gives a prescription for dysentery and diabetes confiding chiefly of "Electri vel succi Nili (Nili succum appellant Arabes Karabem)." {36}

[112] **Page 47, line 22.** Page 47, line 26. *Sudauienses seu Sudini.*—Cardan in *De Rerum Varietate*, lib. iii., cap. xv. (Editio Basil., 1556, p. 152), says of amber:

"Colligitur in quadam penè insula Sudinorum, qui nunc uocātur Brusci, in Prussia, nunc Borussia, juxta Veneticum sinum, & sunt orientaliores ostiis Vistulæ fluuii: ubi triginta pagi huic muneri destinati sunt," etc. He rejects the theory that it consists of hardened gum.

There exists an enormous literature concerning Amber and the Prussian amber industry. Amongst the earliest works (after Theophrastus and Pliny) are those of Aurifaber (*Bericht über Agtstein oder Börnstein*, Königsberg, 1551); Goebel (*De Succino, Libri duo, authore Severino Gœbelio, Medico Doctore*, Regiomont., 1558); and Wigand (*Vera historia de Succino Borussico*, Jena, 1590). Later on Hartmann, P. J. (*Succini Prussici Physica et civilis Historia*, Francofurti, 1677); and the splendid folio of Nathaniel Sendel (*Historia Succinorum corpora aliena involventium*, Lipsiæ, 1742), with its wealth of plates illustrating amber specimens, with the various included fossil fauna and flora. Georgius Agricola (*De natura Fossilium*, liber iv.), and Aldrovandi (*Musæeum Metallicum*, pp. 411-412) must also be mentioned. Bibliographies of the earlier literature are to be found in Hartmann (*op. citat.*), and in Daniel Gralath, *Elektrische Bibliothek* (*Versuche und Abhandlungen der Naturforschenden Gesellschaft in Danzig*, Zweiter Theil, pp. 537-539, Danzig and Leipzig, 1754). See also Karl Müllenhoff, *Deutsche Altertumskunde*, vol. i., Zweites Buch, pp. 211-224, Zinn und Bernsteinhandel (Berlin, 1870), and Humboldt's *Cosmos* (Bohn's edition, London, 1860, vol. ii., p. 493).

The ancient Greek myth according to which amber was the tears of the Heliades, shed on the banks of the river Eridanus over Phaethon, is not alluded to by Gilbert. It is narrated in well-known passages in Ovid and in Hyginus. Those interested in the modern handling of the myth should refer to Müllenhoff (*op. citat.*, pp. 217-223, der Bernsteinmythus), or to that delightful work *The Tears of the Heliades*, by W. Arnold Buffum (London, 1896).

[113] **Page 47, line 30.** Page 47, line 36. *quare & muscos ... in frustulis quibusdam comprehensos retinet.*—The occurrence of flies in amber was well known to the ancients. Pliny thus speaks of it, book xxxvii., chap. iii. (p. 608 of P. Holland's translation of 1601):

"That it doth destill and drop at the first very clear and liquid, it is evident by this argument, for that a man may see diverse things within, to wit, Pismires, Gnats, and Lizards, which no doubt were entangled and stucke within it when it was greene and fresh, and so remain enclosed within as it waxed harder."

A locust embedded in amber is mentioned in the *Musæum Septalianum* of Terzagus (Dertonæ, 1664).

Martial's epigram (*Epigrammata*, liber vi., 15) is well known:

> Dum Phaethontea formica vagatur in umbra
> Implicuit tenuem succina gutta feram.

See also Hermann (Daniel), *De rana et lacerta Succino Borussiaco insitis* (Cracov., 1580; a later edition, Rigæ, 1600). The great work on *inclusa* in amber is, however, that of Nathaniel Sendel. See the previous note. {37}

Sir Thomas Browne must not be forgotten in this connexion. The *Pseudodoxia* (p. 64 of the second edition, 1650) says:

"Lastly, we will not omit what Bellabonus upon his own experiment writ from Dantzich unto Mellichius, as he hath left recorded in his chapter *De Succino*, that the bodies of Flies, Pismires and the like, which are said oft times to be included in Amber, are not reall but representative, as he discovered in severall pieces broke for that purpose. If so, the two famous Epigrams hereof in Martiall are but poeticall, the Pismire of Brassavolus Imaginary, and Cardans Mousoleum for a flie, a meer phancy. But hereunto we know not how to assent, as having met with some whose reals made good their representments." See also Pope's *Epistle to Dr. Arbuthnot*, line 169.

[114] **Page 47, line 34.** Page 47, line 40. *Commemorant antiqui quod succinum festucas et paleas attrahit.*—Pliny (book xxxvii., chap. ii., p. 606 of the English edition of 1601) thus narrates the point:

"Hee [*Niceas*] writeth also, that in Aegypt it [amber] is engendered.... Semblably in Syria, the women (saith hee) make wherves of it for their spindles, where they use to call it Harpax, because it will catch up leaves, straws, and fringes hanging to cloaths."

p. 608. "To come to the properties that Amber hath, If it bee well rubbed and chaufed betweene the fingers, the potentiall facultie that lieth within, is set on work, and brought into actual operation, whereby you shall see it to drawe chaffe strawes, drie leaves, yea, and thin rinds of the Linden or Tillet tree, after the same sort as loadstone draweth yron."

[115] **Page 47, line 36.** Page 47, line 42. *Quod etiam facit Gagates lapis.*—The properties of Jet were well known to the mediæval writers. *Julius Solinus* writes in *De Mirabilibus*, chapter xxxiv., *Of Britaine* (English version of 1587 by A. Golding):

"Moreover to the intent to passe the large aboundance of sundry mettals (whereof Britaine hath many rich mynes on all sides), Here is store of the stone called Geate, and y^{e} best kind of it. If ye demaund y^{e} beautie of it, it is a black Jewell: if the qualitie, it is of no weight: if the nature, it burneth in water, and goeth out in Oyle; if the power, rubbe it till it be warme, and it holdeth such things as are laide to it; as Amber doth. The Realme is partlie inhabited of barbarous people, who even frõ theyr childhoode haue shapes of divers beastes cunninglye impressed and incorporate in theyr bodyes, so that beeing engraued as it were in theyr bowels, as the man groweth, so growe the marks painted vpon him...."

Pliny describes it as follows (p. 589, English edition of 1601):

"The Geat, which otherwise we call Gagates, carrieth the name of a toune and river both in Lycia, called Gages: it is said also, that the sea casteth it up at a full tide or high water into the Island Leucola, where it is gathered within the space of twelve stadia, and no where else: blacke it is, plaine and even, of a hollow substance in manner of the pumish stone, not much differing from the nature of wood; light, brittle, and if it bee rubbed or bruised, of a strong flavour." (Book xxxvi., chap. xviii.)

In the Commentary of Joannes Ruellius upon Dioscorides, *Pedanii Dioscoridis Anazarbei de medicinali materia libri sex, Ioanne Ruellio Suessionensi interprete* ... (Frankfurt, 1543, fol., liber quintus, cap. xcii.) is the following description:

"In Gagatarum lapidum genere, præferendus qui celeriter accenditur, et odorem {38}
bituminis reddit. niger est plerunque, et squalidus, crustosus, per quam levis. Vis ei molliendi, et discutiendi. deprehendit sonticum morbum suffitus, recreatque uuluæ strangulationes. fugat serpentes nidore. podagricis medicaminibus, et a copis additur. In Cilicia nasci solet, qua influens amnis in mare effunditur, proxime oppidum quod Plagiopolis dicitur. vocatur autem et locus et amnis Gagas, in cujus faucibus ii lapides inveniuntur.

"Gagates lapis colore atro, Germanis Schwartzer augstein, voce parum depravata, dicitur. odore dum uritur bituminis, siccat, glutinat, digerit admotus, in corollis precariis et salinis frequens."

And in the *Scholia* upon Dioscorides of Joannes Lonicer (Marpurgi, 1643, cap. xcvii., p. 80) is the following:

"*De Gagate Lapide.* Ab natali solo, urbe nimirum Gagae Lyciae nomen habet. Galenus se flumen isthuc et lapidem non invenisse, etiamsi naui parua totam Lyciam perlustravit: ait, se autem in caua Syria multos nigros lapides invenisse glebosos, qui igni impositi, exiguam flammam gignerent. Meminit hujus Nicander in Theriacis nempe suffitum hujus abigere venenata."

There is also a good account of *Gagates* (and of Succinum) by Langius, *Epistola* LXXV., p. 454, of the work *Epistolarum medicinalium volumen tripartitum* (Francofurti, 1589).

[116] **Page 47, line 39.** Page 47, line 45. *Multi sunt authores moderni.*—The modern authors who raised Gilbert's wrath by ignorantly copying out all the old tales about amber, jet, and loadstone, instead of investigating the facts, were, as he says at the beginning of the chapter, some theologians, and some physicians. He seems to have taken a special dislike to Albertus Magnus, to Puteanus (Du Puys), and to Levinus Lemnius.

[117] **Page 47, line 39.** Page 47, line 46. *& gagate.*—The editions of 1628 and 1633 both read *ex gagate*.

[118] **Page 48, line 14.** Page 48, line 16. *Nam non solum succinum, & gagates (vt illi putant) allectant corpuscula.*—The list of bodies known to become electrical by friction was not quite so restricted as would appear from this passage. Five, if not six, other minerals had been named in addition to amber and jet.

(1.) *Lyncurium.* This stone, about which there has been more obscurity and confusion than about any other gem, is supposed by some writers to be the tourmaline, by others a jacinth, and by others a belemnite. The ancients supposed it to be produced from the urine of the lynx. The following is the account of Theophrastus, *Theophrastus's History of Stones. With an English Version* ..., by "Sir" John Hill, London, 1774, p. 123, ch. xlix.-l.

"There is some Workmanship required to bring the Emerald to its Lustre, for originally it is not so bright. It is, however, excellent in its Virtues, as is also the *Lapis Lyncurius*, which is likewise used for engraving Seals on, and is of a very solid Texture, as Stones are; it has also an attractive Power, like that of Amber, and is said to attract not only Straws and small pieces of Sticks, but even Copper and Iron, if they are beaten to thin pieces. This Diocles affirms. The *Lapis Lyncurius* is pellucid, and of a fire Colour." See also W. Watson in *Philos. Trans.*, 1759, L. i., p. 394, *Observations concerning the Lyncurium of the ancients*.

(2.) *Ruby.*

(3.) *Garnet.* The authority for both these is Pliny, *Nat. Hist.*, book xxxvii., chap. vii. (p. 617 of English edition of 1601).

"Over and besides, I find other sorts of Rubies different from those above-named;... which being chaufed in the Sun, or otherwise set in a heat by rubbing with the fingers, will draw unto them chaffe, strawes, shreads, and leaves of paper. The common Grenat also of Carchedon or Carthage, is said to doe as much, although it be inferiour in price to the former." {39}

(4.) *Jasper.* Affaytatus is the authority, in *Fortunii Affaitati Physici atque Theologi ... Physicæ & Astronomicæ cõsiderationes* (Venet., 1549), where, on p. 20, he speaks of the magnet turning to the pole, likening it to the turning of a "palea ab Ambro vel Iaspide et hujuscemodi lapillis lucidis."

(5.) *Lychnis.* Pliny and St. Isidore speak of a certain stone *lychnis*, of a scarlet or flame colour, which, when warmed by the sun or between the fingers, attracts straws or leaves of papyrus. Pliny puts this stone amongst carbuncles, but it is much more probably *rubellite*, that is to say, red tourmaline.

(6.) *Diamond.* In spite of the confusion already noted, *à propos* of *adamas* (Note to p. **47**), between loadstone and diamond, there seems to be one distinct record of an attractive effect having been observed with a rubbed diamond. This was recorded by Fracastorio, *De sympathia et antipathia rerum* (Giunta edition, Venice, MDLXXIIII, chap. v., p. 60 *verso*), "cujus rei & illud esse signum potest, cum confricata quædã vt Succinum, & Adamas fortius furculos trahunt." And (on p. 62 *recto*); "nam si per similitudine (vt supra diximus) fit hæc attractio, cur magnes non potius magnetem trahit, q̃ ferrum, & ferrum non potius ad ferrum movetur, quàm ad magnetem? quæ nam affinitas est pilorum, & furculorum cum Electro, & Adamante? præsertim q̃ si cum Electro affines sunt, quomodo & cum Adamante affinitatem habebunt, qui dissimilis Electro est?" An incontestable case of the observation of the electrification of the diamond occurs in Gartias ab Horto. The first edition of his *Historia dei Semplici Aromati* was publisht at Goa in India in 1563. In chapter xlviii. on the Diamond, occur these words (p. 200 of the Venetian edition of 1616): "Questo si bene ho sperimentato io più volte, che due Diamanti perfetti fregati insieme, si vniscono di modo insieme, che non di leggiero li potrai separare. Et ho parimente veduto il Diamante dopo di esser ben riscaldato, tirare à se le festuche, non men, che si faccia l'elettro." See also Aldrovandi, *Musæum Metallicum* (Bonon., 1648, p. 947).

Levinus Lemnius also mentions the Diamond along with amber. See his *Occulta naturæ miracula* (English edition, London, 1658, p. 199).

[119] **Page 48, line 16.** Page 48, line 18. *Iris gemma.*—The name *iris* was given, there can be little doubt, to clear six sided prisms of rock-crystal (quartz), which, when held in the sun's beams, cast a crude spectrum of the colours of the rainbow. The following is the account of it given in Pliny, book xxxvii., chap. vii. (p. 623 of the English version of 1601):

"... there is a stone in name called Iris: digged out of the ground it is in a certaine Island of the red sea, distant from the city Berenice three score miles. For the most part it resembleth Crystall: which is the reason that some hath tearmed it the root of Crystall. But the cause why they call it Iris, is, That if the beames of the Sunne strike upon it directly within house, it doth send from it against the walls that bee neare, the very resemblance both in forme and also in colour of a rainebow; and eftsoones it will chaunge the same in much varietie, to the great admiration of them that behold it. For certain it is knowne, that six angles it hath in manner of the Crystall: but they say that some of them have their sides rugged, and the same unequally angled: which if they be laid abroad against the Sunne in the open aire, do scatter the beames of the Sunne, which light upon them too and fro: also that others doe yeeld a brightnes from themselves, and thereby illuminat all that is about them. As for the diverse colours which they cast forth, it never happeneth but in a darke or shaddowie place: whereby a man may know, that the varietie of colours is not in the stone Iris, but commeth by the reverberation of the wals. But the best Iris is that which representeth the greatest circles upon the wall, and those which bee likest unto rainebowes indeed." {40}

In the English translation of Solinus's *De Mirabilibus* (*The excellent and pleasant worke of Julius Solinus containing the noble actions of humaine creatures, the secretes and providence of nature, the descriptions of countries ... tr. by A. Golding, gent.*, Lond., 1587), chapter xv. on Arabia has the following:

"Hee findeth likewise the Iris in the Red sea, sixe cornered as the Crystall: which beeing touched with the Sunnebeames, casteth out of him a bryght reflexion of the ayre like the Raynebowe."

Iris is also mentioned by Albertus Magnus (*De mineralibus*, Venet., 1542, p. 189), by Marbodeus Gallus (*De lapidibus*, Par. 1531, p. 78), who describes it as "crystallo simulem sexangulam," by Lomatius (*Artes of curious Paintinge*, Haydocke's translation, Lond., 1598, p. 157), who says, "... the Sunne, which casting his beames vpon the *stone Iris*, causeth the *raine-bowe* to appeare therein ...," and by "Sir" John Hill (*A General Natural History*, Lond., 1748, p. 179).

Figures of the Iris given by Aldrovandi in the *Musæum Metallicum* clearly depict crystals of quartz.

[120] **Page 48, line 16.** Page 48, line 18. *Vincentina, & Bristolla (Anglica gemma siue fluor)*. This is doubtless the same substance as the *Gemma Vincentij rupis* mentioned on p. **54**, line **16** (p. 54, line 18, of English Version), and is nothing else than the so-called "Bristol diamond," a variety of dark quartz crystallized in small brilliant crystals upon a basis of hæmatite. To the work by Dr. Thomas Venner (Lond., 1650), entitled *Via Recta* or the *Bathes of Bathe*, there is added an appendix, *A Censure concerning the water of Saint Vincents Rocks neer Bristol (Urbs pulchra et Emporium celebre)*, in which, at p. 376, occurs this passage: "This Water of Saint *Vincents* Rock is of a very pure, cleare, crystalline substance, answering to those crystalline Diamonds and transparent stones that are plentifully found in those Clifts."

In the *Fossils Arranged* of "Sir" John Hill (Lond., 1771), p. 123, is the following entry: "Black crystal. Small very hard heavy glossy. Perfectly black, opake. Bristol (grottos, glass)" referring to its use.

The name *Vincentina* is not known as occurring in any mineralogical book. Prof. H. A. Miers, F.R.S., writes concerning the passage: "*Anglica gemma sive fluor* seems to be a synonym for *Bristolla*, or possibly for *Vincentina et Bristolla*. Both quartz and fluor are found at Clifton. In that case Vincentina and Bristolla refer to these two minerals, and if so one would expect Bristolla to be the Bristol Diamond, and Vincentina to be the comparatively rare Fluor spar from that locality."

At the end of the edition of 1653 of Sir Hugh Plat's *Jewel House of Art and Nature*, is appended *A rare and excellent Discourse of Minerals, Stones, Gums, and Rosins; with the vertues and use thereof*, By D. B. *Gent*. Here, p. 218, we read:

"We have in England a stone or mineral called a Bristol stone (because many are found thereabouts) which much resembles the Adamant or Diamond, which is brought out of Arabia and Cyprus; but as it is wanting of the same hardnesse, so falls it short of the like vertues." {41}

[121] **Page 48, line 18.** Page 48, line 19. *Crystallus.*—Rock-crystal. Quartz. Pliny's account of it (Philemon Holland's version of 1601, p. 604) in book xxxvii., chap, ii., is:

"As touching Crystall, it proceedeth of a contrarie cause, namely of cold; for a liquor it is congealed by extreame frost in manner of yce; and for proofe hereof, you shall find crystall in no place els but where the winter snow is frozen hard: so as we may boldly say, it is verie yce and nothing else, whereupon the Greeks have give it the right name Crystallos, *i.* Yce.... Thus much I dare my selfe avouch, that crystall groweth within certaine rockes upon the Alps, and these so steepe and inaccessible, that for the most part they are constrained to hang by ropes that shall get it forth."

[122] **Page 48, line 18.** Page 48, line 20. *Similes etiam attrahendi vires habere videntur vitrum ... sulphur, mastix, & cera dura sigillaris.* If, as shown above, the electric powers of diamond and ruby had already been observed, yet Gilbert was the first beyond question to extend the list of *electrics* beyond the class of precious stones, and his discovery that *glass*, *sulphur*, and *sealing-wax* acted, when rubbed, like amber, was of capital importance. Though he did not pursue the discovery into mechanical contrivances, he left the means of that extension to his followers. To Otto von Guericke we owe the application of sulphur to make the first electrical machine out of a revolving globe; to Sir Isaac Newton the suggestion of glass as affording a more mechanical construction.

Electrical attraction by natural products other than amber after they have been rubbed must have been observed by the primitive races of mankind. Indeed Humboldt in his *Cosmos* (Lond., 1860, vol. i., p. 182) records a striking instance:

"I observed with astonishment, on the woody banks of the Orinoco, in the sports of the natives, that the excitement of electricity by friction was known to these savage races, who occupy the very lowest place in the scale of humanity. Children may be seen to rub the dry, flat and shining seeds or husks of a trailing plant (probably a *Negretia*) until they are able to attract threads of cotton and pieces of bamboo cane."

[123] **Page 48, line 23.** Page 48, line 25. *arsenicum.*—This is *orpiment*. See the *Dictionary of metallick words* at the end of Pettus's *Fleta Minor*.

[124] **Page 48, line 23.** Page 48, line 26. *in convenienti cœlo sicco.*—The observation that only in a dry climate do rock-salt, mica, and rock-alum act as electrics is also of capital importance. Compare page **56**.

[125] **Page 48, line 27.** Page 48, line 31. *Alliciunt hæc omnia non festucas modo & paleas.*—Gilbert himself marks the importance of this discovery by the large asterisk in the margin. The logical consequence was his invention of the first *electroscope*, the *versorium non magneticum*, made of any metal, figured on p. **49**.

[126] **Page 48, line 34.** Page 48, line 36. *quod tantum siccas attrahat paleas, nec folia ocimi.*—This silly tale that basil leaves were not attracted by amber arose in the *Quæstiones Convivales* of Plutarch. It is repeated by Marbodeus and was quoted by Levinus Lemnius as true. Gilbert denounced it as nonsense. Cardan (*De Subtilitate*, Norimb., 1550, p. 132) had already contradicted the fable. "Trahit enim," he says, "omnia levia, paleas, festucas, ramenta tenuia metallorum, & ocimi folia, perperam contradicente {42} Theophrasto." Sir Thomas Browne specifically refuted it. "For if," he says, "the leaves thereof or dried stalks be stripped into small strawes, they arise unto Amber, Wax, and other Electricks, no otherwise then those of Wheat or Rye."

[127] **Page 48, line 34.** Page 48, line 38. *Sed vt poteris manifestè experiri....*

Gilbert's experimental discoveries in electricity may be summarized as follows:

1. The generalization of the class of *Electrics*.
2. The observation that damp weather hinders electrification.
3. The generalization that electrified bodies attract everything, including even metals, water, and oil.
4. The invention of the non-magnetic *versorium* or electroscope.
5. The observation that merely warming amber does not electrify it.
6. The recognition of a definite class of *non-electrics*.
7. The observation that certain electrics do not attract if roasted or burnt.
8. That certain electrics when softened by heat lose their power.
9. That the electric effluvia are stopped by the interposition of a sheet of paper or a piece of linen, or by moist air blown from the mouth.
10. That glowing bodies, such as a live coal, brought near excited amber discharge its power.
11. That the heat of the sun, even when concentrated by a burning mirror, confers no vigour on the amber, but dissipates the effluvia.
12. That sulphur and shell-lac when aflame are not electric.
13. That polish is not essential for an electric.
14. That the electric attracts bodies themselves, not the intervening air.
15. That flame is not attracted.
16. That flame destroys the electrical effluvia.
17. That during south winds and in damp weather, glass and crystal, which collect moisture on their surface, are electrically more interfered with than amber, jet and sulphur, which do not so easily take up moisture on their surfaces.
18. That pure oil does not hinder production of electrification or exercise of attraction.
19. That smoke is electrically attracted, unless too rare.
20. That the attraction by an electric is in a straight line toward it.

[128] **Page 48, line 35.** Page 48, line 39. *quæ sunt illæ materiæ.*—Gilbert's list of electrics should be compared with those given subsequently by Cabeus (1629), by Sir Thomas Browne (1646), and by Bacon. The last-named list occurs in his *Physiological Remains*, published posthumously in 1679; it contains nothing new. Sir Thomas Browne's list is given in the following passage, which is interesting as using for the first time in the English language the noun *Electricities*:

"Many stones also both precious and vulgar, although terse and smooth, have not this power attractive; as Emeralds, Pearle, Jaspis, Corneleans, Agathe, Heliotropes, Marble, Alablaster, Touchstone, Flint and Bezoar. Glasse attracts but weakely though cleere, some slick stones and thick glasses indifferently: Arsenic but weakely, so likewise glasse of Antimony, but Crocus Metallorum not at all. Saltes generally but weakely, as Sal Gemma, Alum, and also Talke, nor very discoverably by any frication: but if gently warmed at the fire, and wiped with a dry cloth, they will better discover their Electricities." *(Pseudodoxia Epidemica*, p. 79.)

In the *Philosophical Transactions*, vol. xx., p. 384, is *A Catalogue of Electrical Bodies* by the late Dr. Rob. Plot. It begins "Non solum succinum," and ends "alumen rupeum," being identical with Gilbert's list except that he calls "Vincentina & Bristolla" by the name "Pseudoadamas Bristoliensis."

[129] **Page 49, line 25.** Page 49, line 30. *non dissimili modo.*—The *modus operandi* of the electrical attractions was a subject of much discussion; see Cardan, *op. citat.* {43}

[130] **Page 51, line 2.** Page 51, line 1. *appellunt.*—This appears to be a misprint for *appelluntur*.

[131] **Page 51, line 22.** Page 51, line 23. *smyris.*—Emery. This substance is mentioned on p. **22** as a magnetic body.

[132] **Page 52, line 1.** Page 51, line 46. *gemmæ ... vt Crystallus, quæ ex limpidâ concreuit.* See the note to p. **48**.

[133] **Page 52, line 30.** Page 52, line 32. *ammoniacum.*—Ammoniacum, or Gutta Ammoniaca, is described by Dioscorides as being the juice of a ferula grown in Africa, resembling galbanum, and used for incense.

"*Ammoniack* is a kind of Gum like Frankincense; it grows in Lybia, where *Ammon's* Temple was." Sir Hugh Plat's *Jewel House of Art and Nature* (Ed. 1653, p. 223).

[134] **Page 52, line 38.** Page 52, line 41. *duæ propositæ sunt causæ ... materia & forma.*—Gilbert had imbibed the schoolmen's ideas as to the relations of matter and form. He had discovered and noted that in the magnetic attractions there was always a verticity, and that in the electrical attractions the rubbed electrical body had no verticity. To account for these differences he drew the inference that since (as he had satisfied himself) the magnetic actions were due to *form*, that is to say to something immaterial—to an "imponderable" as in the subsequent age it was called—the electrical actions must necessarily be due to *matter*. He therefore put forward his idea that a substance to be an electric must necessarily consist of a concreted humour which is partially resolved into an effluvium by attrition. His discoveries that electric actions would not pass through flame, whilst magnetic actions would, and that electric actions could be screened off by interposing the thinnest layer of fabric such as sarcenet, whilst magnetic actions would penetrate thick slabs of every material except iron only, doubtless confirmed him in attributing the electric forces to the presence of these effluvia. See also p. **65**. There arose a fashion, which lasted over a century, for ascribing to "humours," or "fluids," or "effluvia," physical effects which could not otherwise be accounted for. Boyle's tracts of the years 1673 and 1674 on "effluviums," their "determinate nature," their "strange subtilty," and their "great efficacy," are examples.

[135] **Page 53, line 9.** Page 53, line 11. *Magnes vero....*—This passage from line **9** to line **24** states very clearly the differences to be observed between the magnetical and the electrical attractions.

[136] **Page 53, line 36.** Page 53, line 41. *succino calefacto.*—Ed. 1633 reads *succinum* in error.

[137] **Page 54, line 9.** Page 54, line 11. *Plutarchus ... in quæstionibus Platonicis.*—The following Latin version of the paragraph in *Quæstio sexta* is taken from the bilingual edition publisht at Venice in 1552, p. 17 *verso*, liber vii., cap. 7 (or, *Quæstio Septima* in Ed. Didot, p. 1230).

"Electrum uero quæ apposita sunt, nequaquàm trahit, quem admodum nec lapis ille, qui sideritis nuncupatur, nec quicquā à seipso ad ea quæ in propinquo sunt, extrinsecus assilit. Verum lapis magnes effluxiones quasdam tum graves, tum etiam spiritales emittit, quibus aer continuatus & iunctus repellitur. Is deinceps alium sibi proximum impellit, qui in orbem circum actus, atque ad inanem locum rediens, ui ferrum fecum rapit & trahit. At Electrum uim quandam flammæ similem & spiritalem continet, quam quidem tritu {44} summæ partis, quo aperiuntur meatus, foras eijcit. Nam leuissima corpuscula & aridissima quæ propè sunt, sua tenuitate atque imbecillitate ad seipsum ducit & rapit, cum non sit adeo ualens, nec tantum habeat ponderis & momenti ad expellendam aeris copiam, ut maiora corpora more Magnetis superare possit & uincere."

[138] **Page 54, line 16.** Page 54, line 18. *Gemma Vincentij rupis.*—See the note to p. **48** *supra*, where the name *Vincentina* occurs.

[139] **Page 54, line 30.** Page 54, line 35. *orobi.*—The editions of 1628 and 1633 read *oribi*.

[140] **Page 55, line 34.** Page 55, line 42. *in euacuati.*—The editions of 1628 and 1633 read *inevacuati*.

[141] **Page 58, line 21.** Page 58, line 25. *assurgentem vndam ... declinat ab F.*—These words are wanting in the Stettin editions.

[142] **Page 59, line 9.** Page 59, line 9. *fluore.*—This word is conjectured to be a misprint for *fluxu* but it stands in all editions.

[143] **Page 59, line 22.** Page 59, line 25. *Ruunt ad electria.*—This appears to be a slip for *electrica*, which is the reading of the editions of 1628 and 1633.

[144] **Page 60, line 7.** Page 60, line 9. *tanq̄ materiales radij.*—The suggestion here of

material *rays* as the *modus operandi* of electric forces seems to foreshadow the notion of electric lines of force.

[145] **Page 60, line 10.** Page 60, line 12. *Differentia inter magnetica & electrica.*—Though Gilbert was the first systematically to explore the differences that exist between the magnetic attraction of iron and the electric attraction of all light substances, the point had not passed unheeded, for we find St. Augustine, in the *De Civitate Dei*, liber xxi., cap. 6, raising the question why the loadstone which attracts iron should refuse to move straws. The many analogies between electric and magnetic phenomena had led many experimenters to speculate on the possibility of some connexion between electricity and magnetism. See, for example, Tiberius Cavallo, *A Treatise on Magnetism*, London, 1787, p. 126. Also the three volumes of J. H. van Swinden, *Receuil de Mémoires sur l'Analogie de Electricité et du Magnétisme*, La Haye, 1784. Aepinus wrote a treatise on the subject, entitled *De Similitudine vis electricæ et magneticæ* (Petropolis, 1758). This was, of course, long prior to the discovery, by Oersted, in 1820, of the real connexion between magnetism and the electric current.

[146] **Page 60, line 25.** Page 60, line 31. *Coitionem dicimus, non attractionem.*—See the remarks, at the outset of these Notes, on Gilbert's definitions of words.

[147] **Page 60, line 33.** Page 61, line 1. *Orpheus in suis carminibus.*—This passage is in the chapter Λιθικά of Orpheus, verses 301 to 327. See Note to p. **11**, line **19**.

[148] **Page 61, line 15.** Page 61, line 19. *Platonis in Timæo opinio.*—The passage runs (edition Didot, vol. ii., p. 240, or Stephanus, p. 80, C.):

Καὶ δὴ καὶ τὰ τῶν ὑδάτων πάντα ῥεύματα ἔτι δὲ τὰ τῶν κεραυνῶν πτώματα καὶ τὰ θαυμαζόμενα ἠλέκτρων περὶ τῆς ἕλξεως καὶ τῶν Ἡρακλείων λίθων, πάντων τούτων ὁλκὴ μὲν οὐκ ἔστιν οὐδένι ποτε, τὸ δὲ κενὸν εἶναι μηδεν περιωθεῖν τε αὐτὰ ταῦτα εἰς ἄλληλα, τό τε διακρινόμενα καὶ συγκρινόμενα πρὸς τήν αὐτῶν διαμειβόμενα ἕδραν ἕκαστα ἰέναι πάντα, τούτοις τοῖς παθήμασι πρὸς ἄλληλα συμπλεχθεῖσι τεθαυματουργημένα τῷ κατὰ τρόπον ζητοῦντι φανήσεται.

[149] **Page 61, Line 30.** Page 61, line 38. The English version of the lines of Lucretius is from Busby's translation.

[150] **Page 62, line 5.** Page 62, line 7. *Iohannes Costæus Laudensis.*—Joannes Costa, of Lodi, edited Galen and Avicenna. He also wrote a *De universali stirpium Natura* (Aug. Taurin., 1578). {45}

[151] **Page 63, line 3.** Page 63, line 4. *Cornelius Gemma 10. Cosmocrit.*—This refers to the work *De Naturæ Divinis Characterismis ... Libri ii. Avctore D. Corn. Gemma* (Antv., 1575, lib. i., cap. vii., p. 123).

"Certè vt à magnete insensiles radij ferrum ad se attrahunt, ab echineide paruo pisciculo sistuntur plena nauigia, à catoblepa spiritu non homines solùm, sed & alta serpentum genera interimuntur, & saxa dehiscunt."

See also Kircher's *Magneticum Naturæ Regnum* (Amsterodami, 1667, p. 172), Sectio iv., cap. iii., De Magnete Navium, quæ Remora seu Echeneis dicitur. See the note to p. **7**, line **21**.

[152] **Page 63, line 6.** Page 63, line 7. *Guilielmus Puteanus.*—Puteanus (Du Puys) wrote a work *De Medicamentorum quomodocunque Purgantium Facultatibus*, Libri ii. (Lugd., 1552), in which he talks vaguely about the substantial "form" of the magnet, and quotes Aristotle and Galen.

[153] **Page 63, line 21.** Page 63, line 25. *Baptistæ Portæ.*—The passage in the translation is quoted from the English version of 1658, pp. 191, 192.

[154] **Page 64, line 4.** Page 64, line 9. *Eruditè magis Scaliger.*—Gilbert pokes fun at Scaliger, whose "erudite" guess (that the motion of iron to the magnet was that of the offspring toward the parent) is to be found in his book *De Subtilitate, ad Cardanum*, Exercitatio CII. (Lutetiæ, 1557, p. 156 *bis*).

[155] **Page 64, line 7.** Page 64, line 11. *Diuus Thomas.*—On p. **3** Gilbert had already spoken of St. Thomas Aquinas as a man of intellect who would have added more about the magnet had he been more conversant with experiments. The passage here quoted is from the middle of Liber vii. of his commentaries on the *de Physica* of Aristotle, *Expositio Diui Thome Aquinatis Doctoris Angelici super octo libros Physicorum Aristotelis*, etc. (Venice, Giunta edition, 1539, p. 96 *verso*, col. 2).

[156] **Page 64, line 16.** Page 64, line 24. *Cardinalis etiam Cusanus.*—Cardinal de Cusa (Nicolas Khrypffs) wrote a set of dialogues on Statics, *Nicolai Cusani de staticis experimentis dialogus* (1550), of which an English version appeared in London in 1650 with the title, *The Idiot in four books; the first and second of wisdom, the third of the minde, the fourth of statick experiments. By the famous and learned C. Cusanus.* In the fourth book *of statick Experiments, Or experiments of the Ballance*, occurs (p. 186) the following:

"*Orat.* Tell me, if thou hast any device whereby the vertues of stones may be weighed.

"*Id.* I thinke the vertue of the Load-stone might be weighed, if putting some Iron in one scale, and a Load-stone in the other, untill the ballance were even, then taking away the Load-stone, and some other thing of the same weight being put into the scale, the Load-stone were holden over the Iron, so that that scale wou'd begin to rise; by reason of the Load-stones attraction of the Iron, then take out some of the weight of the other scale, untill the scale wherein the iron is, doe sinke againe to the æquilibrium, or equality still holding the Load-stone unmovable as it was; I beleeve that by weight of what was taken out of the contrary scale, one might come proportionably to the weight of the vertue or power of the Load-stone. And in like manner, the vertue of a Diamond, might be found hereby, because they say it {46} hinders the Load-stone from drawing of Iron; and so other vertues of other stones, consideration, being alwayes had of the greatnesse of the bodyes, because in a greater body, there is a greater power and vertue."

In the 1588 edition of Baptista Porta's *Magiæ Naturalis Libri xx.*, in lib. vii., cap. xviii., occurs the description of the use of the balance to which Gilbert refers.

[157] **Page 67, line 21.** Page 67, line 22. *aëris rigore.*—All editions read thus, but the sense seems to require *frigore*.

[158] **Page 67, line 27.** Page 67, line 31. *Fracastorius.*—See his *De Sympathia*, lib. i., cap. 5 (Giunta edition, 1574, p. 60).

[159] **Page 68, line 5.** Page 68, line 6. *Thaletis Milesij.*—See the note to p. **11**, line **26**.

[160] **Page 68, line 30.** Page 68, line 35. *Ità coitio magnetica actus est magnetis, & ferri, non actio vnius.*—See the introductory remarks to these notes. There is a passage in Scaliger's *De Subtilitate ad Cardanum* (Exercitat. CII., cap. 5, p. 156 *op. citat.*) which may be compared with Gilbert's for its use of Greek terms: "Nã cùm uita dicatur actus animæ, acceptus est abs te actus pro actione. Sed actus ille est ἐντελέχεια, nõ autem ἔργον. At Magnetis attractio est ἔργον, non autẽ ἐντελέχεια." To which Gilbert retorts: "non actio unius, utriusque ἐντελέχεια; non ἔργον, συνεντελέχεια et conactus potius quam sympathia." He returns on p. **70** to the attack on Scaliger's metaphysical notions. There is a parallel passage in the *Epitome Naturalis Scientiæ* of Daniel Sennert (Oxoniæ, 1664), in the chapter *De Motu*.

[161] **Page 71, line 4.** Page 71, line 8. *vt in 8. physicorum Themistius existimat.*—See *Omnia Themistii Opera* (Aldine edition, 1533, p. 63), Book 8 of his Paraphrase on Aristotle's *Physica*.

[162] **Page 71, line 9.** Page 71, line 14. *Quod verò Fracastorius.—Op. citat.*, lib. i., cap. 7, p. 62 *verso*.

[163] **Page 73, line 2.** Page 73, line 2. *si A borealis.*—The editions of 1628 and 1633 omit the twelve words next following.

[164] **Page 73, line 9.** Page 73, line 11. *ex minera.—Minera* is not a recognized word, even in late Latin. It occurs again, p. **97**, line **12**.

[165] **Page 77, line 2.** Page 77, line 2. *multo magis.*—This is an *à fortiori* argument. It is interesting to find Gilbert comparing the velocity of propagation of magnetic forces in space with the velocity of light. The parallel is completed in line 13 by the consideration that as the rays of light require to fall upon an object in order that they may become visible, so the magnetic forces require a magnetic object in order to render their presence sensible.

[166] **Page 78, line 14.** Page 78, line 16. *Orbem terrarum distinguunt.*—The editions of 1628 and 1633 here add a figure of a globe marked with meridians and parallels of latitude, but with an erroneous versorium pointing to the south. These editions also both read *existentiam* for the word *existentium* in line **20**.

[167] **Page 83, line 5.** Page 83, line 5. *magnes longior maiora pondera ferri attollit.*—Gilbert discovered the advantage, for an equal mass of loadstone, of an elongated shape. It is now well known that the specific amount of magnetism retained by elongated forms exceeds that in a short piece of the same material subjected to equal magnetizing forces.

[168] **Page 83, line 24.** Page 83, line 28. *Non obstant crassa tabulata.*—Gilbert has several times referred (*e.g.*, on p. **77**) to the way in which magnetic forces penetrate solid bodies. The experimental investigation in this chapter is the more interesting because it {47} shows that Gilbert clearly perceived the shielding action of iron to be due to iron conducting aside or diverting the magnetic forces.

[169] **Page 85, line 26.** Page 85, line 31. *non conveniant.*—The editions of 1628 and 1633 both read *et conveniant*.

[170] **Page 86, line 3.** Page 86, line 3. *illud quod exhalat.*—Literally, *that which exhales*,

in the sense of that which escapes: but in modern English the verb exhale in the active voice is now not used of the substance that escapes, but is used of the thing which emits it. It must therefore be rendered *that which is exhaled* (*i.e.*, breathed out).

[171] **Page 86, line 13.** Page 86, line 15. *Ita tota interposita moles terrestris.*—Gilbert's notion that the gravitational force of the moon in producing the tides acts *through* the substance of the earth may seem curiously expressed. But the underlying contention is essentially true to-day. The force of gravity is not cut off or screened off by the interposition of other masses. A recent investigation by Professor Poynting, F.R.S., has shown that so far as all evidence goes all bodies, even the densest, are transparent with respect to gravitational forces.

[172] **Page 86, line 18.** Page 86, line 20. *Sed de æstus ratione aliàs.*—There is no further discussion of the tides in *De Magnete*. But a short account is to be found in Gilbert's posthumous work *De Mundo nostro Sublunari Philosophia nova* (Amsterdam, Elzevir, 1651), in Lib. v., the part which in the manuscript was left in English, and was turned into Latin by his brother. It comprises about fifteen quarto pages, from Cap. X. to Cap. XIX. inclusive, beginning with a characteristic diatribe against Taisnier, Levinus Lemnius, and Scaliger. But in assigning causes he himself goes wide of the mark. Proceeding by a process of elimination he first shows that the moon's light cannot be the cause that impels the tides. "Luna," he says, "non radio, non lumine, maria impellit. quomodo igitur? Sane corporum conspiratione, acque (ut similitudine rem exponam) Magnetica attractione." This cryptic utterance he proceeds to explain by a diagram, and adds: "Quare Luna non tam attrahit mare, quàm humorem & spiritum subterraneum; nec plus resistit interposita terra, quàm mensa, aut quicquam aliud densum, aut crassum, magnetis viribus."

[173] **Page 87, line 7.** Page 87, line 9. *armatura.*—Here this means the cap or snout of iron with which the loadstone was armed. This is apparently the first use of the term in this sense.

In the *Dialogues of Galileo* (p. 369 of Salusbury's *Mathematical Collections*, Dialogue iii.), Sagredus and Salviatus discuss the arming of the loadstone, and the increased lifting power conferred by adding an iron cap. Salviatus mentions a loadstone in the Florentine Academy which, unarmed, weighed six ounces, lifting only two ounces, but which when armed took up 160 ounces. Whereupon Galileo makes Salviatus say: "I extreamly praise, admire, and envy this Authour, for that a conceit so stupendious should come into his minde. ... I think him [*i.e.*, Gilbert] moreover worthy of extraordinary applause for the many new and true Observations that he made, to the disgrace of so many fabulous Authours, that write not only what they do not know, but whatever they hear spoken by the foolish vulgar, never seeking to assure themselves of the same by experience, perhaps, because they are unwilling to diminish the bulk of their Books."

[174] **Page 87, line 12.** Page 87, line 15. The reference to *lib.* 3 is a misprint for *lib.* 2. It is corrected in the edition of 1633, but not in that of 1628. {48}

[175] **Page 87, line 17.** Page 87, line 21. *conactu.*—The editions of 1628 and 1633 read *conatu*.

[176] **Page 88, line 2.** Page 88, line 3. *Coitio verò non fortior.*—This heading to chap. xix., taken with the seven lines that follow, and the contrast drawn between *unitio* and *coitio*, throw much light on the fundamental sense attached by Gilbert to the term *coitio*. It is here clearly used in the sense of *mutual tendency toward union*. Note also the contrasted use in chap. xx. of the verbs *cohære* and *adhære*. Adhærence connotes a one-sided force (an impossibility in physics), cohærence a mutual force.

[177] **Page 90, line 9.** Page 90, line 9. *nempè vt alter polus maius pondus arripiat.*—This acute observation is even now not as well known as it ought to be. Only so recently as 1861 Siemens patented the device of fastening a mass of iron to one end of an electromagnet in order to increase the power of the other end. The fact, so far as it relates to permanent magnets was known to Servington Savery. See *Philos. Transactions*, 1729, p. 295.

[178] **Page 92, line 3.** Page 92, line 4. *Suspendit in aëre ferrum Baptista Porta.*—Porta's experiment is thus described (*Natural Magick*, London, 1658, p. 204): "*Petrus Pellegrinus* saith, he shewed in another work how that might be done: but that work is not to be found. Why I think it extream hard, I shall say afterwards. But I say it may be done, because I have now done it, to hold it fast by an invisible band, to hang in the air; onely so, that it be bound with a small thread beneath, that it may not rise higher: and then striving to catch hold of the stone above, it will hang in the air, and tremble and wag itself."

[179] **Page 97, line 29.** Page 97, line 33. *Sed quæri potest ...*—The question here raised by Gilbert is whether the lifting-power of magnets of equal quality is proportional to their weight. If a stone weighing a drachm will lift a drachm, would a stone that weighs an ounce lift an ounce? Gilbert erroneously answers that this is so, and that the lifting-power of a loadstone, whether armed or unarmed, is proportional to its mass.

The true law of the tractive force or lifting-power of magnets was first given in 1729 by James Hamilton (afterwards Earl of Abercorn) in a work entitled *Calculations and Tables Relating to the Attractive Virtue of Loadstones ... Printed* [at London?] *in the Year* 1729. (See also a paper in the *Philos. Transactions*, 1729-30, vol. xxxvi., p. 245). This work begins thus:

"The Principle upon which these Tables are formed, is this: That if Two *Loadstones* are perfectly Homogeneous, that is, if their Matter be of the same Specifick Gravity, and of the same Virtue in all Parts of one Stone, as in the other; and that Like Parts of their Surfaces are Cap'd or Arm'd with Iron; then the Weights they sustain will be as the Squares of the Cube Roots of the Weights of the *Loadstones*; that is, as their Surfaces."

Upon lifting-power see also D. Bernoulli, *Acta Helvetica*, iii., p. 223, 1758; P. W. Haecker, *Zur Theorie des Magnetismus*, Nürnberg, 1856; Van der Willigen, *Arch. du Musée Teyler*, vol. iv., Haarlem, 1878 ; S. P. Thompson, *Philos. Magazine*, July, 1888.

In the book of James Hamilton, p. 5, he mentions a small terrella weighing 139 English grains, which would sustain no less than 23,760 grains, and was valued at £21 13*s.* 10¾*d.*

In the *Musæum Septalianum* of Terzagus (Dertonæ, 1664, p. 42) is mentioned a {49}
loadstone weighing twelve ounces which would lift sixty pounds of iron.

Sir Isaac Newton had a loadstone weighing 3 grains, which he wore in a ring. It would lift 746 grains.

Thomson's *British Annual*, 1837, p. 354, gives the following reference: "In the *Records of General Science*, vol. iii., p. 272, there is an interesting description of a very powerful magnet which was sent from Virginia in 1776 by the celebrated Dr. Franklin to Professor Anderson, of Glasgow. It is now in the possession of Mr. Crichton. It weighs 2½ grains, and is capable of supporting a load of 783 grains, which is equivalent to 313 times its own weight."

[180] **Page 99, line 10.** Page 99, line 11. *Manifestum est.*—In this, as in many other passages, Gilbert uses this expression in the sense that *it is demonstrable* rather than meaning that *it is obvious*: for the fact here described is one that is not at all self-evident, but one which would become plain when the experiment had been tried. For other instances of this use of *manifestum* see pages **144**, line **20**; **158**, line **19**; **162**, line **10**.

[181] **Page 100, line 20.** Page 100, line 24. *si per impedimēta ... pervenire possunt.*—All editions agree in this reading, but the sense undoubtedly requires *non possint*. Compare p. **91**, line **21**.

[182] **Page 102, line 4.** Page 102, line 4. *capite* 4.—This is a misprint for *capite* 40, and is retained in the later editions. In the quotation from Baptista Porta, where the English version of 1658 is adhæred to, the words "& deturbat eam" have been omitted by the translator.

[183] **Page 107, line 16.** Page 107, line 18. *Cardanus scribit.*—The alleged perpetual motion machine is mentioned in *De rerum varietate, lib.* 9, cap. xlviii. (Basil., 1581, p. 641). See also the Note to p. **223**. For Peregrinus and for Taisnier, see the note to p. **5**, lines **8** and **12**.

[184] **Page 107, line 19.** Page 107, line 21. *Antonij de Fantis.*—His work is: *Tabula generalis scotice subtilitatis octo Sectionibus vniuersam Doctoris Subtilis Peritiā cōplectēs: ab excellentissimo doctore Antonio de Fātis taruisino edita ...* Lugd., 1530.

[185] **Page 108, line 26.** Page 108, line 31. *Cusani in staticis.*—See the note to p. **64**, line **16**.

[186] **Page 108, line 33.** Page 108, line 41. *Languidi ... tardiùs acquiescunt.*—The editions of 1628 and 1633 omit these seven words.

[187] **Page 109, line 11.** Page 109, line 13. *halinitro.*—Either native carbonate of soda or native carbonate of potash might be meant, but not saltpetre. Scaliger, in his *De Subtilitate ad Cardanum* (Lutet., 1557, p. 164), *Exercitatio* CIII., 15, under the title, *Nitrum non est Salpetræ*, says: "More tuo te, tuaque confundis. Salpetræ inter salis fossilis ponis hîc. Mox Halinitrum inter salis, & nitri naturam, speciem obtinere."

"*Sal nitrum* is salt which is boiled out of the earth, especially fat earth, as in stables, or any place of excrements." (*A Chymicall Dictionary explaining Hard Places and Words met withall in the Writings of Paracelsus ...*, Lond., 1650.)

[188] **Page 109, line 20.** Page 109, line 23. *arte ioculatoriâ.*—Edition 1628, *joculatoriâ*; edition 1633, *jaculatoriâ*.

[189] **Page 110, line 11.** Page 110, line 12. *qualis fuit Antonij denarius.*—The Elizabethan version of Pliny (book xxxiii., ch. ix., p. 479) runs thus: "To come now unto {50}
those that counterfeit money. *Antonius* whiles hee was one of the three usurping Triumvirs, mixed yron with the Romane silver denier. He tempered it also with the brasen coine, and so sent abroad false and counterfeit money."

Georgius Agricola (*De Natura Fossilium*, p. 646) says:

"Sed ea fraus capitalis est, non aliter ac eorum qui adulterinas monetas cudunt, argento miscentes multam plumbi candidi portionem, aut etiam ferri, qualis fuit Antonii denarius, ut Plinius memoriæ tradidit. Nunc dicam de candido plumbo, nam majoris pretii est quàm aes. In quod plumbum album, inquit Plinius, addita aeris tertia portione candidi adulteratur stannum."

[190] **Page 111, line 3.** Page 111, line 3. *Meminerunt Chatochitis lapis Plinius, atque Iulius Solinus.*—The passage in Pliny (English version of 1601, book xxxvii., ch. x., p. 625) runs:

"Catochitis is a stone proper unto the Island Corsica: in bignesse it exceedeth ordinarie pretious stones: a wonderfull stone, if all be true that is reported thereof, and namely, That if a man lay his hand thereon, it will hold it fast in manner of a glewie gum."

[191] **Page 111, line 7.** Page 111, line 7. *Sagda vel Sagdo.*—Albertus Magnus in *De Mineralibus* (Venet., 1542, p. 202) says:

"Sarda quem alij dicunt Sardo lapis est qui se habet ad tabulas ligni sicut magnes ad ferrū, et ideo adhæret ita fortiter tabulis nauium quòd euelli nō possit, nisi abscindatur cum ipso ea pars tabulæ cui inhæserit, est autē in colore purissimus nitens."

And Pliny (*op. citat.*, p. 629):

"Sagda is a stone, which the Chaldeans find sticking to ships, and they say it is greene as Porrets or Leekes."

[192] **Page 111, line 8.** Page 111, line 8. *Euace.*—Evax, king of the Arabs, is said to have written to Nero a treatise on the names, colours, and properties of stones. See the note on Marbodæus, p. **7**, line **20**.

[193] **Page 113, line 14.** Page 113, line 19. *repulsus sit.* The words read thus in all editions, but the sense requires *repulsa sint.*

[194] **Page 113, line 23.** Page 113, line 29. *Electrica omnia alliciunt cuncta, nihil omninò fugant vnquam, aut propellunt.* This denial of electrical repulsion probably arose from the smallness of the pieces of electric material with which Gilbert worked. He could hardly have failed to notice it had he used large pieces of amber or of sealing-wax. Electrical repulsion was first observed by Nicolas Cabeus, *Philosophia Magnetica*, Ferrara, 1629; but first systematically announced by Otto von Guericke in his treatise *Experimenta Nova (ut vocantur) Magdeburgica, de Vacuo Spatio* (Amstel., 1672).

[195] **Page 113, line 29.** Page 113, line 37. *cùm de calore quid sit disputabimus.*—The discussion of the nature of heat is to be found in Gilbert's *De Mundo nostro Sublunari* (Amstel., 1651), lib. i., cap. xxvi., pp. 77-88.

[196] **Page 115, line 23.** Page 115, line 23. *trium vel quatuor digitorum.*—Here as in all other places in Gilbert, *digitus* means a finger's breadth, so that three or four digits means a length of two or three inches, or from six to eight centimetres.

[197] **Page 117, line 26.** Page 117, line 25. *ille Thebit Bencoræ trepidationis motus.*

"Trepidation in the ancient Astronomy denotes a motion which in the Ptolemaic system was attributed to the firmament, in order to account for several changes and motions observed in the axis of the world, and for which they could not account on any other principle." (Barlow's *Mathematical Dictionary.*) {51}

[198] **Page 118, line 10.** Page 118, line 8. *cuspis is aut lilium.*—Gilbert uses *cuspis* or *lilium* always of the North-pointing end of the needle. Sir Thomas Browne speaks of "the lilly or northern point"; but he differs from Gilbert in saying "the *cuspis* or Southern point" (*Pseudodoxia Epidemica*, 1650, p. 46). Only in one place (p. **101**, line **5**) does Gilbert speak of *cuspis meridionalis*. Everywhere else the south-pointing end is called the *crux*.

[199] **Page 118, line 15.** Page 118, line 13. *nam æquè potens est.*—Later observation showed this view to be incorrect. The horizontal component of the earth's magnetic field is not equally strong all over the globe, and the sluggishness of the needle's return to its position of rest is not due to the supporting pin becoming blunt with wear. The value of the horizontal component is zero at the north magnetic pole, and increases toward the magnetic equator. It is greatest near Singapore and in Borneo, being there more than twice as great as it is at London. (See Captain Creak in *Report of Voyage of H.M.S. Challenger, Physics and Chemistry*, vol. ii., part vi., 1889.)

[200] **Page 119, line 5.** Page 119, line 2. *lapis.*—Both Stettin editions read *lapidis.*

[201] **Page 119, lines 9-11.** Page 119, lines 7-9. The gist of the whole book is summarized in these lines. They furnish a cardinal example of that inductive reasoning which was practist by Gilbert, and of which Bacon subsequently posed as the apostle. Compare pages **41** and **211**.

[202] **Page 120, line 8.** Page 120, line 5. *dicturi sumus.*—Change of verticity is treated of in book iii., chap. x., pp. **137** to **140**.

[203] **Page 125, line 24.** Page 125, line 29. *appositam.*—All editions give this word, though the sense requires *appositum.*

[204] **Page 128, line 9.** Page 128, line 11. *non nimis longum.*—The editions of 1628 and 1633 read (wrongly) *minus* instead of *nimis*.

[205] **Page 130, line 12.** Page 130, line 14. The word *hunc* in the folio of 1600 is corrected in ink to *tunc*, and the Stettin editions both read *tunc*.

[206] **Page 132, line 9.** Page 132, line 10. *minimus & nullius ponderis.*—The editions of 1628 and 1633 both wrongly read *est* for *&*.

[207] **Page 132, line 28.** Page 133, line 1. *nutat.*—The editions of 1628 and 1633 both wrongly read *mutat*.

[208] **Page 134, line 22.** Page 134, line 25. *in rectâ sphærâ.*—The meaning of the terms a *right* or *direct sphere*, an *oblique sphere* and a *parallel sphere* are explained by Moxon on pages 29 to 31 of his book *A Tutor to Astronomy and Geography* (Lond., 1686):

"A *Direct Sphere* hath both the *Poles* of the *World* in the Horizon ... It is called a *Direct Sphere*, because all the *Celestial* Bodies, as *Sun*, *Moon*, and *Stars*, &c. By the *Diurnal* Motion of the *Primum Mobile*, ascend directly Above, and descend directly Below the *Horizon*. They that Inhabit under the *Equator* have the *Sphere* thus posited."

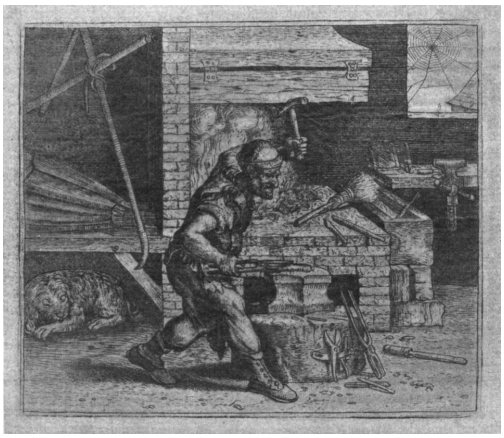
"An *Oblique Sphere* hath the *Axis* of the *World* neither *Direct* nor *Parallel* to the *Horizon*, but lies aslope from it."

"A *Parallel Sphere* hath one *Pole* of the *World* in the *Zenith*, the other in the *Nadir*, and the *Equinoctial* Line in the *Horizon*."

[209] **Page 136, line 1.** Page 136, line 1. *præsenti.*—The editions of 1628 and 1633 read *sequenti*, to suit the altered position of the figure.

[210] **Page 137, line 24.** Page 137, line 28. *atque ille statim.*—The Stettin editions both wrongly read illi. {52}

[211] **Page 139.** There is a curious history to this picture of the blacksmith in his smithy striking the iron while it lies north and south, and so magnetizing it under the influence of the earth's magnetism. Woodcuts containing human figures are comparatively rare in English art of the sixteenth century; a notable exception being Foxe's *Acts and Monuments* with its many crude cuts of martyrdoms. The artist who prepared this cut of the smith took the design from an illustrated book of Fables by one Cornelius Kiliani or Cornelius van Kiel entitled *Viridarium Moralis Philosophiæ, per Fabulas Animalibus brutis attributas traditæ, etc.* (Coloniæ, 1594). This rare work, of which there is no copy in the British Museum, is illustrated by some 120 fine copper-plate etchings printed in the text. On p. 133 of this work is an etching to illustrate the fable *Ferrarii fabri et canis*, representing the smith smiting iron on the anvil, whilst his lazy dog sleeps beneath the bellows. The cut on p. **139** of Gilbert gives, as will be seen by a comparison of the pictures just the same general detail of forge and tools; but the position of the smith is reversed right for left, the dog is omitted, and the words *Septrenio* and *Auster* have been added.



In the Stettin edition of 1628 the picture has again been turned into a copper-plate etching separately printed, is reversed back again left for right, while a compass-card is introduced in the corner to mark the north-south direction.

In the Stettin edition of 1633 the artist has gone back to Kiliani's original plate, and has re-etched the design very carefully, but reversing it all right for left. As in the London version of 1600, the dog is omitted, and the words *Septentrio* and *Auster* are added. Some of the original details—for example, the vice and one pair of pincers—are left out, but other details, for instance, the cracks in the blocks that support the water-tub, and the dress of the blacksmith, are rendered with slavish fidelity. {53}

It is perhaps needless to remark that the twelve copper-plate etchings in the edition of 1628, and the twelve completely different ones in that of 1633, replace certain of the woodcuts of the folio of 1600. For example, take the woodcut on p. **203** of the 1600 edition, which represents a simple dipping-needle made by thrusting a versorium through a bit of cork and floating it, immersed, in a goblet of water. In the 1633 edition this

appears, slightly reduced, as a small inserted copper-plate, with nothing added; but in the 1628 edition it is elaborated into a full-page plate (No. xi.) representing the interior, with shelves of books, of a library on the floor of which stands the goblet—apparently three feet high—with a globe and an armillary sphere; while beside the goblet, with his back to the spectator, is seated an aged man, reading, in a carved armchair. This figure and the view of the library are unquestionably copied—reversed—from a well-known plate in the work *Le Diverse & Artificiose Machine* of Agostino Ramelli (Paris, 1558).

In the Emblems of Jacob Cats (*Alle de Wercken*, Amsterdam, 1665, p. 65) is given an engraved plate of a smith's forge, which is also copied—omitting the smith—from Kiliani's *Viridarium*.

[212] **Page 140, line 2.**. Page 140, line 2. *præcedenti.*—This is so spelled in all editions, though the sense requires *præcedente*.

[213] **Page 141, line 21.** Page 141, line 24. *quod in epistolâ quâdam Italicâ scribitur.*—The tale told by Filippo Costa of Mantua about the magnetism acquired by the iron rod on the tower of the church of St. Augustine in Rimini is historical. The church was dedicated to St. John, but in the custody of the Augustinian monks. The following is the account of it given by Aldrovandi, *Musæum Metallicum* (1648, p. 134), on which page also two figures of it are given:

"Aliquando etiam ferrum suam mutat substantiam, dum in magnetem conuertitur, & hoc experientia constat, nam Arimini supra turrim templi S. Ioannis erat Crux a baculo ferreo ponderis centum librarum sustentata, quod tractu temporis adeò naturam Magnetis est adeptum, vt, illivs instar, ferrum traheret: hinc magna admiratione multi tenentur, qua ratione ferrum, quod est metallum in Magnetem, qui est lapis transmutari possit; Animaduertendum est id à maxima familiaritate & sympathia ferri, & magnetis dimanare cum Aristoteles in habentibus symbolum facilem transitum semper admiserit. Hoc in loco damus imaginem frusti ferri in Magnetem transmutati, quod clarissimo viro Vlyssi Aldrouando Iulius Caesar Moderatus diligens rerum naturalium inquisitor communicauit; erat hoc frustum ferri colore nigro, & ferrugineo, crusta exteriori quodammodo albicante." And further on p. 557.

"Preterea id manifestissimum est; quoniam Arimini, in templo Sancti Ioannis, fuit Crux ferrea, quæ tractu temporis in magnetem conuersa est, & ab vno latere ferrum trahebat, & ab altero respuebat." See also Sir T. Browne's *Pseudodoxia Epidemica* (edition of 1650, p. 48), and Boyle's tract, *Experiments and Notes about the Mechanical Production of Magnetism* (London, 1676, p. 12).

Another case is mentioned in Dr. Martin Lister's *A Journey to Paris* (Lond., 1699, p. 83). {54}
"He [Mr. Butterfield] shewed us a Loadstone sawed off that piece of the Iron Bar which held the Stones together at the very top of the Steeple of *Chartres*. This was a thick Crust of Rust, part of which was turned into a strong Loadstone, and had all the properties of a Stone dug out of the Mine. *Mons. de la Hire* has Printed a Memoir of it; also Mons. *de Vallemont* a Treatise. The very outward Rust had no Magnetic Virtue, but the inward had a strong one, as to take up a third part more than its weight unshod." Gassendi and Grimaldi have given other cases.

Other examples of iron acquiring strong permanent magnetism from the earth are not wanting. The following is from Sir W. Snow Harris's *Rudimentary Magnetism* (London, 1872, p. 10).

"In the *Memoirs of the Academy of Sciences* for 1731, we find an account of a large bell at Marseilles having an axis of iron: this axis rested on stone blocks, and threw off from time to time great quantities of rust, which, mixing with the particles of stone and the oil used to facilitate the motion, became conglomerated into a hardened mass: this mass had all the properties of the native magnet. The bell is supposed to have been in the same position for 400 years."

[214] **Page 142, line 13.** Page 142, line 15. *tunc planetæ & corpora cœlestia.*—Gilbert's extraordinary detachment from all metaphysical and ultra-physical explanations of physical facts, and his continual appeal to the test of experimental evidence, enabled him to lift the science of the magnet out of the slough of the dark ages. This passage, however, reveals that he still gave credence to the *nativities* of judicial Astrology, and to the supposed influence of the planets on human destiny.

[215] **Page 144, line 14.** Page 144, line 14. *ijdem.*—The editions of 1628 and 1633 erroneously read *iisdem*.

[216] **Page 147, line 27.** Page 147, line 29. *ex optimo aciario.*—Gilbert recommended that the compass-needle should be of the best steel. Though the distinction between iron and steel was not at this time well established, there is no reason to doubt that by *aciarium* was meant edge-steel as used for blades. Barlowe, in his *Magneticall Advertisements* (Lond., 1616), p. 66, gives minute instructions for the fashioning of the compass-needle. He gives the preference to a pointed oval form, and describes how the steel must be hardened by heating to whiteness and quenching in water, so that it is "brickle in a manner as glass it selfe," and then be tempered by reheating it over a bar of

red hot iron until it is let down to a blue tint. Savery (*Philos. Trans.*, 1729) appears to have been the first to make a systematic examination of the magnetic differences between hard steel and soft iron.

Instructions for touching the needle are given in the *Arte de Nauegar* of Pedro de Medina (Valladolid, 1545, lib. vi., cap. 1).

[217] **Page 149, line 8.** Page 149, line 9. *per multa sæcula.*—Compare Porta's assertion (p. 208, English edition) "iron once rubbed will hold the vertue a hundred years." Clearly not a matter within the actual experience of either Porta or Gilbert.

[218] **Page 153, line 2.** Page 153, line 2. *Cardani ab ortu stellæ in cauda vrsæ.*—What Cardan said (*De Subtilitate, Edit. citat.*, p. 187) was: "ortum stellæ in cauda ursæ minoris, quæ quinque partibus orientalior est polo mundi, respicit."

[219] **Page 153, line 21.** Page 153, line 26. *sequitur quod versus terram magnam, siue continentem ... à vero polo inclinatio magnetica fiat.*—Gilbert goes on to point out how, at {55} that date, all the way up the west European coast from Morocco to Norway, the compass is deflected eastward, or toward the elevated land. He argued that this was a universal law.

In *Purchas his Pilgrimes* (Lond., 1625), in the Narrative, in vol. iii., of Bylot and Baffin's Voyage of 1616, there is mentioned an island between Whale-Sound and Smith's Sound, where there had been observed a larger variation than in any other part of the world. Purchas, in a marginal note, comments on this as follows: "Variation of the Compass 56° to the West, which may make questionable D. Gilbert's rule, tom. 1., l. 2, c. 1, that where more Earth is more attraction of the Compass happeneth by variation towards it. Now the known Continents of Asia, &c., must be unspeakably more than here there can be, & yet here is more variation then about Jepan, Brasil, or Peru, &c."

Gilbert's view was in truth founded on an incomplete set of facts. At that time, as he tells us, the variation of the compass at London was 11⅓ degrees eastward. But he did not know of the secular change which would in about fifty-seven years reduce that variation to zero. Still less did he imagine that there would then begin a westward variation which in the year 1816 should reach 24° 30', and which should then steadily diminish so that in the year 1900 it should stand at 16° 16' westward. For an early discussion of the changes of the variation see vol. i. of the *Philosophical Transactions* (Abridged), p. 188. Still earlier is the classical volume of Henry Gellibrand, *A Discovrse Mathematical on the Variation of the Magneticall Needle* (Lond., 1635). Gilbert heads chapter iii. of book iiii. (p. **159**) with the assertion *Variatio uniuscuiusque loci constans est*, declaring that to change it would require the upheaval of a continent. Gellibrand combats this on p. 7 of the work mentioned. He says:

> "Thus hitherto (according to the Tenents of all our *Magneticall* Philosophers) we have supposed the variations of all particular places to continue one and the same. So that when a Seaman shall happly returne to a place where formerly he found the same variation, he may hence conclude he is in the same former *Longitude*. For it is the Assertion of *Mr. Dr. Gilberts*. *Variatio vnicuiusq; Loci constans est*, that is to say, the same place doth alwayes retaine the same variation. Neither hath this Assertion (for ought I ever heard) been questioned by any man. But most diligent magneticall observations have plainely offred violence to the same, and proved the contrary, namely that the variation is accompanied with a variation."

In 1637 Henry Bond wrote in the *Sea-Mans Kalendar* that in the year 1657 the variation would be zero at London. Compare Bond's *Longitude Found* (Lond., 1676, p. 3).

As to inconstancy of the variation in one place see further Fournier's *Hydrographie* (Paris, 1667, liv. xi., ch. 12, p. 413), and Kircher, *Magnes* (Colon. Agripp., 1643, p. 418).

[220] **Page 157, line 4.** Page 157, line 5. *perfecto.*—Though this word is thus in all editions, it ought to stand *perfectâ*, as in line **10** below.

[221] **Page 157, line 11.** Page 157, line 13. *varietas*, for *variatio*.

[222] **Page 160, line 20.** Page 160, line 23. *in Borrholybicum.*—This name for the North-west, or North-North-West, is rarely used. It is found on the chart or windrose of the names of the winds on pp. 151 and 152 of the *Mécometrie de l'Eyman* of G. Nautonier (1602). Here the name *Borrolybicus* is given as a synonym for *Nortouest Galerne*, or Ὀλυμπιάς, while the two winds on the points next on the western and northern sides respectively are called *Upocorus* and *Upocircius*.

In Swan's *Specvlvm Mundi* (Camb., 1643, p. 174) is this explanation: "Borrholybicus is {56} the North-west wind."

In Kircher's *Magnes* (Colon. Agripp., 1643, p. 434) is a table of the names of the thirty-two winds in six languages, where *Borrolybicus* is given as the equivalent of *Maestro* or *North-West*.

[223] **Page 161, line 2.** Page 161, line 2. *Insula in Oceano variationem non mutat.*—The

conclusions derived from the magnetic explorations of the Challenger expedition, 1873-1876, are briefly these: That in islands north of the magnetic equator there is a tendency to produce a local perturbation, attracting the north-seeking end of the needle downwards, and horizontally towards the higher parts of the land; while south of the magnetic equator, the opposite effects are observed. (See *Challenger Reports, Physics and Chemistry*, vol. ii., part vi., *Report on the Magnetical Results* by Staff-Commander Creak, F.R.S.)

[224] **Page 162, line 2.** Page 162, line 3. *quarè & respectiuum punctum ... excogitauit.*—The passage referred to is in *The newe Attractiue* of Robert Norman (Lond., 1581), chap. vi.

"Your reason towards the earth carrieth some probabilitie, but I prove that there be no *Attractive*, or drawing propertie in neyther of these two partes, then is the *Attractive* poynt lost, and falsly called the poynt *Attractive*, as shall be proved. But because there is a certayne point that the Needle alwayes respecteth or sheweth, being voide and without any *Attractive* propertie: in my judgment this poynt ought rather to bee called the point Respective ... This Poynt *Respective*, is a certayne poynt, which the touched Needle doth alwayes *Respect* or shew ..."

[225] **Page 165, line 2.** Page 165, line 2. *De pyxidis nauticæ vsitatæ compositione.*—Gilbert's description of the usual construction of the mariner's compass should be compared with those given by Levinus Lemnius in *The Secret Miracles of Nature* (London, 1658); by Lipenius in *Navigatio Salomonis Ophiritica* (Witteb., 1660, p. 333); and with that given in Barlowe's *Navigators Supply* (London, 1597). See also Robert Dudley's *Dell' Arcano del Mare* (Firenze, 1646).

[226] **Page 165** deals with the construction; the process of magnetizing by the loadstone had already been discussed in pp. **147** to **149**. It is interesting to see that already the magnetized part attached below the compass-card was being specialized in form, being made either of two pieces bent to meet at their ends, or of a single oval piece with elongated ends. The marking of the compass-card is particularly described. It was divided into thirty-two points or "winds," precisely as the earlier "wind-rose" of the geographers, distinguisht by certain marks, and by a lily—or fleur-de-lys—indicating the North. Stevin in the *Havenfinding Art* (London, 1599), from which work the passage on p. **167** is quoted, speaking on p. 20 of "the Instrument which we call the Sea-directorie, some the nautical box, ... or the sea compasse," mentions the "Floure de luce" marking the North.

The legend which assigns the invention of the compass to one Goia or Gioja of Amalfi in 1302 has been already discussed in the Note to page **4**. Gilbert generously says that in spite of the adverse evidence he does not wish to deprive the Amalfians of the honour of the construction adopted in the compasses used in the Mediterranean. But Baptista Porta the Neapolitan, who wrote forty years before Gilbert, discredited the legend. "*Flavius* saith, an Italian found it out first, whose name was *Amalphus*, born in our Campania. But {57} he knew not the Mariners Card, but stuck the needle in a reed, or a piece of wood, cross over; and he put the needles into a vessel full of water that they might flote freely." (Porta's *Natural Magick*, English translation, London, 1658, p. 206.) See also Lipenius (*op. citat.* p. 390).

The pivotting of the needle is expressly described in the famous *Epistle* on the Magnet of Peter Peregrinus, which was written in 1269. Gasser's edition, *Epistola Petri Peregrini ... de magnete*, was printed in Augsburg in 1558. In Part II., cap. 2, of this letter, a form of instrument is described for directing one's course to towns and islands, and any places in fact on land or sea. This instrument consists of a vessel like a turned box (or *pyxis*) of wood, brass, or any solid material, not deep, but sufficiently wide, provided with a cover of glass or crystal. In its middle is arranged a slender axis of brass or silver, pivotted at its two ends into the top and the bottom of the box. This axis is pierced orthogonally with two holes, through one of which is passed the steel needle, while through the other is fixed square across the needle another stylus of silver or brass. The glass cover was to be marked with two cross lines north-south and east-west; and each quadrant was to be divided into ninety degrees. This the earliest described pivotted compass was therefore of the cross-needle type, a form claimed as a new invention by Barlowe in 1597. The first suggestion of suspending a magnetic needle by a thread appears to be in the *Speculum Lapidum* of Camillus Leonardus (Venet., 1502, fig. k ij, lines 25-31): "Nã tacto ferro ex una pte magnetis ex opposita eius pte appropinquato fugat: ut expiẽtia docet de acu appenso filo."

The earliest known examples of the "wind-rose" are those in certain parchment charts preserved in the Biblioteca Marciana in Venice. These go back to 1426 or 1436, the best being ascribed to Andrea Bianco. They have the North indicated by a fleur-de-lys, a trident, a simple triangle, or a letter T; while the East is distinguisht by a cross. The West is marked with a P. (see Fincati, *op. citat.*). The eight marks in order, clock wise, run thus,

 (or T). G.  (or L) S. O. A (or L). P. M.

The letters correspond to the Italian names of the principal winds:

Tramontano	North.
Greco	North-East.
Levante	East.
Sirocco	South-East.
Ostro	South.
Africo or Libeccio	South-West.
Ponente	West.
Maestro	North-West.

Wind-roses marked with the names of the minor winds are found in Nautonier's *Mécometrie de l'Eyman* (Vennes, 1602-1604, pp. 151-152), and Kircher's *Magnes Siue de Arte Magnetica* (Colon. Agripp., 1643, p. 432). The description above given of the early Venetian wind-roses *exactly* describes the compass-card as depicted by Pedro de Medina in his *Arte de Nauegar* (Valladolid, 1545, folio lxxx.), in the sixth book entitled "las aguias de navegar"; while in the *Breve compendio de la sphera* of Martin Cortes (Sevilla, 1551, cap. iii., *de la piedrayman*) a similar wind-rose, without the letters, is found.

In the *De Ventis et navigatione* of Michaele Angelo Blondo (Venet., 1546, p. 15) is given a {58}
wind-rose, described as "Pixis uel Buxolus instrumentum et dux nauigantium," having twenty-six points inscribed with the names of the winds, there being six between north and east, and six between south and west, and only five in each of the other quadrants. In the middle is a smaller wind-rose exactly like the early Italian ones just mentioned.

In the *Della Guerra di Rhodi* of Jacobo Fontano (Venet., 1545, pages 71-74) is a chapter *Dei Venti, e della Bvssola di nauicare di Giovanni Quintino*, giving a wind-rose, and a table of the names of the winds, the north being indicated by a pointer, at the cusp of which are seven stars, and the west by an image of the sun. The other cardinal points are marked with letters.

Barlowe, in *The Navigators Supply* (Lond., 1597), speaks thus:

> "The merueilous and diuine Instrument, called the *Sayling Compasse* (being one of the greatest wonders that this World hath) is a Circle diuided commonly into 32. partes, tearmed by our Seamen Windes, *Rumbes*, or Points of Compasse."

It is a disputed point with whom the method of naming the winds originated. Some ascribe it to Charlemagne. Michiel Coignet (*Instruction novvelle ... touchant l'art de naviguer*, Anvers, 1581, p. 7) ascribes it to Andronicus Cyrrhestes. See Varro, *De Re Rustica*, iii., 5, 17, and Vitruvius, i., 6, 4.

Gilbert's complaint of the evil practice of setting the needles obliquely beneath the card, with the intention of allowing for the variation, is an echo of a similar complaint in Norman's *Newe Attractiue*. In chapter x. of this work Norman thus enumerates the different kinds of compasses:

> "Of these common Sayling Compasses, I find heere (in *Europa*) five sundry sortes or sets. The first is of *Levant*, made in *Scicile*, *Genoüa*, and *Venice*: And these are all (for the most parte) made Meridionally, with the Wyers directlye sette under the South, and North of the Compasse: And therefore, duely shewing the poynt *Respective*, in all places, as the bare Needle. And by this Compasse are the Plats made, for the most part of all the *Levants* Seas.
>
> "Secondly, there are made in *Danske*, in the Sound of *Denmarke*, and in *Flanders*, that have the Wyers set at 3 quarters of a point to the Eastwards of the North of the compasse, and also some at a whole point: and by these Compasses they make both the Plats and Rutters for the Sound.
>
> "Thirdly, there hath beene made in this Countrey particulary, for Saint *Nicholas* and *Ruscia*, Compasses set at 3 seconds of a point, and the first Plats of that Discoverie were made by this Compasse.
>
> "Fourthly the Compasse made at *Sevill*, *Lisbone*, *Rochell*, *Bourdeaux*, *Roan*, and heere in *England*, are moste commonly set at halfe a point: And by this Compasse are the Plats of the East and West *Indies* made for their Pylotes, and also for our Coastes neere hereby, as *France*, *Spayne*, *Portugall*, and *England*: and therefore best of these Nations to bee used, because it is the most common sorte that is generally used in these Coastes."

Bessard (*op. citat.*, pages 22 and 48) gives cuts of compasses showing the needle displaced one rumbe to the East.

Gallucci, in his *Ratio fabricandi horaria mobilia et permanentia cum magnetica acu* (Venet., 1596), describes the needle as inclined 10 degrees from the south toward the south-west.

The frontispiece of the work of Pedro Nuñez, *Instrumenta Artis Navigandi*, Basil., 1592, depicts a compass with the lily set one point to the east.

Reibelt, *De Physicis et Pragmaticis Magnetis Mysteriis* (Herbipolis, 1731), depicts the compass with the needle set about 12 degrees to the East of North. See also Fournier, *Hydrographie* (Paris 1667); De Lanis, *Magisterium Natvræ et Artis* (Brixiæ, 1684); Milliet Deschales, *Cursus seu Mundus Mathematicus* (Lugd., 1674). Both the latter works give {59} pictures of the compass-cards as used in South Europe, and in North Europe, and of the various known shapes of needles.

[227] **Page 168, line 29.** Page 168, line 33. *Directio igitur inualidior est propè polos.* Here as in many passages *direction* means *the force which directs*. A similar usage prevails with the nouns *variation* and *declination*, meaning frequently the force causing variation or declination respectively.

Page 172, line 13. *perquirere.* The edition of 1633 reads *perquirero*, in error.

[228] **Page 172, line 29.** Page 172, line 33. *Ad pyxidis nauticæ veræ & meridionalis formam ... fiat instrumentum.*—An excellent form of portable meridian compass, provided with sights for taking astronomical observations, is described by Barlowe (*The Navigators Supply*, London, 1597), and is depicted in an etched engraving. An identical engraving is repeated in Dudley's *Arcano del Mare* (Firenze, 1646). Gilbert's new instrument was considerably larger.

[229] **Page 174, line 19.** Page 174, line 21. *addendo vel detrahendo prostaphæresin.* —"Prosthaphæresis, conflata dictione, ex additione et subtractione speciebus logistices, nomen habet ab officio, quia vt in semicirculo altero ad æquabilem motum adijcitur, ita in altero subtrahitur, vt adparens motus ex æquabili taxetur: atque hinc fit, quòd quæ Prosthaphæresis dicitur Ptolemæo, ea vulgò æquatio vocetur." (Stadius, *Tabulæ Bergenses*, Colon. Agripp., 1560, p. 37.)

[230] **Page 174, line 28.** Page 174, line 31. *Stellæ Lucidæ.*—According to Dr. Marke Ridley (*Magneticall Animadversions*, London, 1617, p. 9), this chapter xii. of book iv., with the Table of Stars, was written by Edward Wright, the author of the Prefatory Epistle of *De Magnete*. Wright was Lecturer on Navigation to the East India Company, and author of sundry treatises on Navigation.

[231] **Page 187, line 14.** Page 187, line 16. *hic qui versus boream constitit ... meridionalis est, non borealis, quem antè nos omnes existimabant esse borealem.*—Earlier on, on pages **15** and **125**, Gilbert had mentioned this point. His insistence caused Barlowe (*Magneticall Aduertisements*, 1616, p. 4) to speak of the south-pointing end of the needle as the "true North," and thereby drew on himself the animadversions of Marke Ridley.

[232] **Page 188, line 15.** Page 188, line 16. *in rectâ sphærâ.*—See note to p. **134**.

[233] **Page 190, line 14.** Page 190, line 19. *declinans in Borealibus.*—Dipping as it does in northern regions; that is, with the north-seeking or true-south pole downward.

[234] **Page 195, line 20.** Page 195, line 24. *multa maiora pondera.*—Many greater weights. All editions read *multa*, but the sense requires *multo*: "much greater weights."

[235] **Page 196, line 10.** Page 196, line 12. *constans est.*—This must not be read "is constant," for it is constant only in any given latitude.

[236] **Page 196, line 15.** Page 196, line 18. *De proportione declinationis pro latitudinis ratione.*—Gilbert here announces, and proceeds in the next seven pages to develop, the proposition that to each latitude there corresponds a constant dip to a particular number of degrees. If this were accurately so, then a traveller by merely measuring the dip would be able to ascertain, by calculation, by reference to tables, or by aid of some geometrical appliance, the latitude of the place. In this hope Gilbert fought to perfect the dipping- {60} needle; and he also worked out, on pages **199** and **200**, an empirical theory, and a diagram. This theory was still further developed by him, and given to Thomas Blundevile (see the Note to p. **240**). Briggs of Gresham College, on Gilbert's suggestion, calculated a table of Dip and Latitude on this theory. It was found, however, that the observed facts deviated more or less widely from the theory. Kircher (*Magnes*, 1643, p. 368) gives a comparative table of the computed and observed values. Further discovery showed the method to be impracticable, and Gilbert's hope remained unfulfilled.

[237] **Page 197, line 18.** Page 197, line 21. *progressionis centri.*—Note Gilbert's precision of phrase.

[238] **Page 200, line 12.** Page 200, line 11. *subintelligūtur.*—This is printed *subintelligitur*, and is altered in ink in all copies of the folio edition. The editions of 1628 and 1633 read *subintelliguntur*. Similarly in line **14** the word *ducit* has had a small *r* added in ink, making it read *ducitur*, as also the other editions.

[239] **Page 203.** This figure of the experiment with the simple dipping needle suspended in water in a goblet is due to Robert Norman. In his *Newe Attractiue* (London, 1581, chap. vi.) he thus describes it:

"Then you shall take a deepe Glasse, Bowle, Cuppe, or other vessell, and fill it with

fayre water, setting it in some place where it may rest quiet, and out of the winde. This done, cut the Corke circumspectly, by little and little, untill the wyre with the Corke be so fitted, that it may remain under the superficies of the water two or three inches, both ends of the wyer lying levell with the superficies of the water, without ascending or descending, like to the beame of a payre of ballance beeing equalie poysed at both ends.

"Then take out of the same the wyer without mooving the Corke, and touch it with the *Stone*, the one end with the South of the *Stone*, and the other end with the North, and then set it againe in the water, and you shall see it presentlie turne it selfe upon his owne Center, shewing the aforesay'd *Declining* propertie, without descending to the bottome, as by reason it should, if there were any *Attraction* downewards, the lower part of the water being neerer that point, then the superficies thereof."

[240] **Page 212, line 7.** Page 212, line 8. *ex altera parte.*—The sense seems to require *et altera parte*, but all editions read *ex*.

[241] **Page 213, line 1.** Page 213, line 2. The passage here quoted from Dominicus Maria Ferrariensis, otherwise known as the astronomer Novara, does not occur in any known writing of that famous man. It is, however, quoted as being by Novara in at least three other writings of the same epoch. See the *Tabulæ secvndorum mobilium coelestium* of Maginus (Venet., 1585, p. 29, line 19 to p. 30, line 11); the *Eratosthenes Batavvs* of Willebrord Snell (Lugd. Batav., 1617, pp. 40-42); and the *Almagesti novi (Pars Posterior)* of Riccioli (Bonon., 1651, p. 348). The original document appears to have perisht. See a notice by M. Curtze in Boncompagni's *Bullettino di Bibliografia*, T. iv., April, 1871.

[242] **Page 214, line 26.** Page 214, line 31. *Philolaus Pythagoricus.*

"Philolaüs a le premier dit que la terre se meut en cercle; d'autres disent que c'est Nicétas de Syracuse."

"Les uns prétendent que le terre est immobile; mais Philolaüs le pythagoricien dit qu'elle se meut circulairement autour du feu (central) et suivant un cercle oblique, comme le soleil et la lune."—(Chaignet, *Pythagore et la Philosophie pythagoricienne*, Paris, 1873.)

It appears that the first of these *dicta* is taken from Diogenes Laërt., viii. 85; and the second from Plutarch, *Placit. Philos.*, III. 7. The latter passage may be compared with {61}
Aristotle, *De Coelo*, II. 13, who, referring to the followers of Pythagoras, says: "They say that the middle is fire, that the earth is a star, and that it is moved circularly about this centre; and that by this movement it produces day and night."

[243] **Page 214, line 34.** Page 214, line 42. *Copernicus.*—His work is *De revolutionibus orbium coelestium, libri vi.* (Basil., 1566).

[244] **Page 215, line 27.** Page 215, line 24. *quæ ... in cælo varijs distantijs collocata sunt.*—This remark appears to be Gilbert's one contribution to the science of Astronomy; the stars having previously been regarded as fixed in the eighth sphere all at the same distance from the central earth, around which it revolved.

[245] **Page 220, line 6.** Page 220, line 6. *quem nycthemeron vocamus.*—The 1628 and 1633 editions read *nyctemoron*.

[246] **Page 221, line 10.** Page 221, line 11. *poli verè oppositi sint.*—For *verè*, the 1628 and 1633 editions read *rectæ*. All editions read *sint*, though *sunt* seems to make better sense.

[247] **Page 223, line 7.** Page 223, line 8. *ad telluris conformitatem.*—The word *conformitas* is unknown in classical Latin.

[248] **Page 223, line 16.** Page 223, line 17. *Omitto quod Petrus Peregrinus constanter affirmat, terrellam super polos suos in meridiano suspensam, moveri circulariter integrâ revolutione 24 horis: Quod tamen nobis adhuc videre non contingit; de quo motu etiam dubitamus.*

This statement that a spherical loadstone pivotted freely with its axis parallel to the earth's axis will of itself revolve on its axis once a day under the control of the heavens, thus superseding clocks, is to be found at the end of chap. x. of Peregrinus's *Epistola De Magnete* (Augsb., 1537).

Gilbert, who doubted this experiment because of the stone's own weight is taken to task by Galileo, in the third of his Dialogues, for his qualified admission.

"I will speak of one particular, to which I could have wished that *Gilbert* had not lent an ear; I mean that of admitting, that in case a little Sphere of Loadstone might be exactly librated, it would revolve in it self; because there is no reason why it should do so" (p. 376 of Salusbury's *Mathematical Collections*, London, 1661). The Jesuit Fathers who followed Gilbert, but rejected his Copernican ideas, pounced upon this pseudo-

experiment, as though by disproving it they had upset the Copernican theory.

[249] **Page 227, line 6.** Page 227, line 7. This line is left out in the 1628 edition. In the 1633 edition it was also left out by the printer, and subsequently printed in in the margin, being page 219 of that edition.

[250] **Page 234, line 35.** Page 234, line 40. *vt poli telluris respectus à polis.*—If it may be permitted to read *respectu* for *respectus* the sense is improved, and the passage may then be translated thus: "that just as it was needful ... that the poles of the Earth as to direction should be 23 degrees and more from the poles of the Ecliptick; so now, &c."

[251] **Page 237, line 19.** Page 237, line 22. *vt motus quidem obscuri saluarentur.*—It has been conjectured that *quidem* is here a misprint for *quidam*, but the adverb *quidem* adds a satirical flavour to his argument against the folly of those who held the doctrine of the moving spheres. The verb *salvare* does not occur in classical Latin.

[252] **Page 240, line 13.** Page 240, line 17. *à Copernico (Astronomiæ instauratore).*— Gilbert was the first in England to uphold the doctrines of Copernicus as to the motion of {62}
the earth on its axis and its revolution around the sun. He considered that his magnetic observations brought new support to that theory, and his views are quoted with approbation by Kepler, *Epitome Astronomiæ Copernicanæ* ... Authore Ioanne Keplero ... (Francofurti, 1635); and by Galileo, *Dialogus de Systemate Mundi* (Augustæ Treboc., 1635), an English translation of which appeared in Salusbury's *Mathematical Collections and Translations* (London, 1661, pp. 364 to 377).

For this the book *De Magnete* was considered by many as heretical. Many of the copies existing in Italy are found to be either mutilated or else branded with a cross. For example, the copy in the library of the Collegio Romano in Rome has book VI. torn out. Galileo states that the Book of Gilbert would possibly never have come into his hands "if a Peripatetick Philosopher, of great fame, as I believe to free his Library from its contagion, had not given it me." In England Barlowe, in his *Magneticall Aduertisements* (1616), expressly repudiated Gilbert's Copernican notions, while praising his discoveries in magnetism. Marke Ridley, while upholding Gilbert's views, in his *Magneticall Animadversions* (1617) did not consider him "skilfull in Copernicus." The Jesuit writers, Cabeus, Kircher, Fonseca, Grandamicus, Schott, Leotaudus, Millietus, and De Lanis, one and all, who followed Gilbert in their magnetic writings, repudiated the idea that the magnetism of the globe gave support to the heretical modern Astronomy.

The works referred to are:

Cabeus, *Philosophia Magnetica, in qua Magnetis natura penitus explicatur ... auctore Nicolao Cabeo Ferrarensi Soc. Jesv.* (Ferrariæ, 1629).

Kircher, *Magnes, Siue de Arte Magnetica, Libri tres, Authore Athanasio Kirchero ... e Soc. Iesv.* (Romæ, 1641).

Grandamicus, *Nova Demonstratio immobilitatis terræ petita ex virtute magnetica* (Flexiæ, 1645). This work is most beautifully illustrated with copper-plate etchings of cupids making experiments with terrellas.

Schott, Gaspar, *Thaumaturgus Physicus* (Herbipolis, 1659).

Leotaudus, *R. P. Vincentinii Leotavdi Delphinatis, Societ. Iesv., Magnetologia; in qva exponitvr Nova de Magneticis Philosophia*, (Lvgdvni, 1668).

Millietus (Milliet Deschales), *Cursus seu Mundus Mathematicus* (Lugd., 1674), *Tomus Primus, Tractatus de Magnete*.

De Lanis, *Magisterium Natvræ et Artis. Opus Physico-Mathematicvm P. Francisci Tertii de Lanis, Soc. Jesv.* (Brixiæ, 1684).

[253] **Page 240, line 24.** Page 240, line 31. *hic finem & periodum imponimus.*

On February 13 [1601] Gilbert wrote to Barlowe (see *Magneticall Aduertisements*, p. 88):

"I purpose to adioyne an appendix of six or eight sheets of paper to my booke after a while, I am in hand with it of some new inventions, and I would haue some of your experiments, in your name and inuention put into it, if you please, that you may be knowen for an augmenter of that arte."

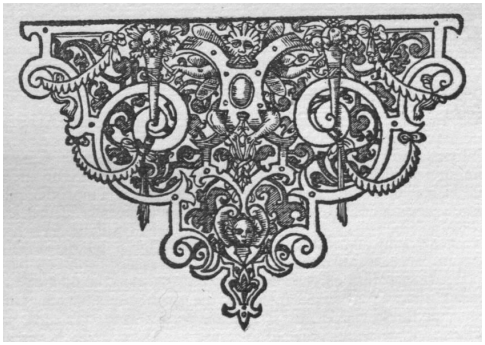
This he never did. Perhaps his appointment (in February, 1601) as chief physician in personal attendance on the Queen interfered with the project; or his death, of the plague, in 1603, intervened before his intention had been carried into effect. But it is probable that the substance of the proposed additions is to be found in the chapter, publisht in Gilbert's lifetime, in Blundevile's *Theoriques of the seuen Planets* (London, 1602), thus described in the title-page of the work: "There is also hereto added, The making, {63}
description, and vse, of two most ingenious and necessarie Instruments for Sea-men, to find out thereby the latitude of any Place vpon the Sea or Land, in the darkest night that is, without the helpe of Sunne, Moone, or Starre. First inuented by M. Doctor Gilbert, a most excellent Philosopher, and one of the ordinarie Physicians to her Maiestie: and now here plainely set downe in our mother tongue by Master Blundeuile."

Of these two instruments the first consists of a mechanical device, with movable quadrants, to be cut out in cardboard, to be used in connection with the diagram of spiral lines which Gilbert had given as a folding plate between pages **200** and **201** of *De Magnete*. The intention was that the Sea-man having found by experiment with a dipping-needle the amount of the dip at any place, should by applying this diagram and its moving quadrants, ascertain the latitude, according to the theory expounded in book V., chap. VII.

The second instrument is a simplified portable dipping-needle, having the degrees engraved on the inner face of a cylindrical brass ring.

Blundevile adds a Table, calculated by Briggs, and "annexed to the former Treatise by *Edward Wright*, at the motion of the right Worshipful M. Doctor *Gilbert*." This gives the values of the dip for different latitudes, as calculated from Gilbert's empirical theory.

The other work, *De Mundo nostro Sublunari Philosophia Nova*, which Gilbert left in manuscript at his death, does not contain any additional matter on the magnetical investigations. Though it contains several direct references to the *de Magnete*, and particularly to Book VI. on the rotation of the earth, it is doubtful whether it was written after or before the publication of *de Magnete*. On pages 137 to 144 of the posthumous edition (Amsterdam, 1651) Gilbert refers to Peregrinus's alleged perpetually revolving sphere, and denies its possibility. The greater part of the work is an anti-Aristotelian discussion on Air, Meteorology, Astronomy, the Winds, Tides, and Springs.



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