William 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 / William Gilbert.

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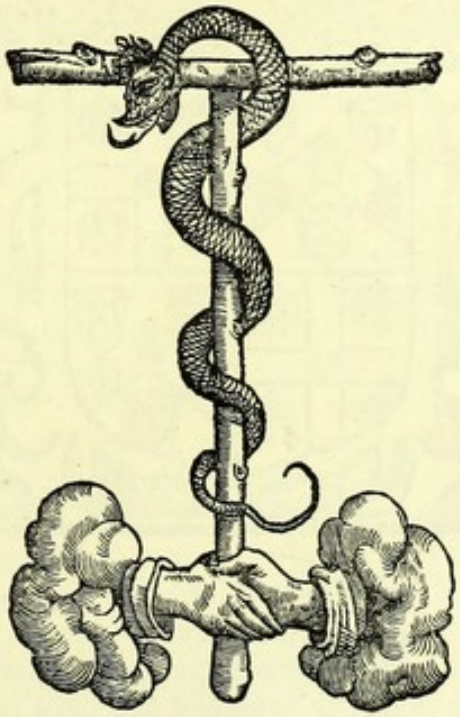
VVILLIAM GILBERT OF COLCHESTER, PHYSICIAN OF LONDON.

ON THE MAGNET, MAGNETICK BODIES ALSO, AND ON the great magnet the earth; a new Physiology, *demonstrated by many arguments & experiments.*



LONDON

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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

monly 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.

TO

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;*

directed; it began alſo long ago to ſhow diſtinctly the diſtance of the place toward which it 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

whole ſky. For in the firſt place it is againſt reaſon that that ſhould be 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.

Interpretation

Interpretation of certain words.

TErrella, a globular loadſtone.

Verticity, polar vigour, not περιδίνησις, but περιδίνειστος 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

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.

AT 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*, Ariſtotle in the *De Anima*, in Book I. only, Theophraſtus the Leſbian, Dioſcorides, C. Plinius Secundus, and Julius Solinus. As handed down by them the loadſtone merely attracted iron, the reſt of its virtues were all undiſcovered. But that the ſtory of the load-

ſtone might not appear too bare and too brief, to this ſingular and ſole known quality there 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. 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 out 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, 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, 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 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, Arnaldus. Bare mention is made of certain points relating to the loadſtone in very few words by Marbodeus Gallus, Albertus,

Matthæus

Matthæus Silvaticus, Hermolaus Barbarus, Camillus Leonhardus, Cornelius Agrippa, Fallopius, 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 Puteanus in his *Ratio Purgantium Medicamentorum* diſcuſſes the loadſtone briefly and learnedly. Thomas Eraſtus, knowing little of magnetical nature, finds in the loadſtone weak arguments againſt Paracelſus; Georgius Agricola, like Encelius 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, 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, and infers its antiquity on certain grounds; he does not divulge the hidden miracle which he propounds. In the kingdom

of

of Naples the Amalfians were the firſt (ſo it is ſaid) to conſtruct the mariners' compaſs: and as Flavius Blondus ſays the Amalfians 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, 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 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*, 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. Gonzalus Oviedus is the firſt to write, as he does in his *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

For clumſy, 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, 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 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 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 conſiders that there is a place of attraction beyond the poles, which he judges to be the moving heavens. One Beſſardus, a Frenchman, with no leſs folly notes the pole of the zodiack. Jacobus Severtius, 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, an Engliſhman, fixes a point and region reſpective, not attractive; to which the magnetical iron is collimated, but is not itſelf attracted. Franciſcus Maurolycus 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. Joſephus Acoſta, though quite ignorant about the loadſtone, nevertheleſs pours forth vapid talk upon the loadſtone. Livio Sanuto in his Italian *Geographia*, diſcuſſes at length the queſtion whether the prime magnetick meridian

meridian and the magnetick poles are in the heavens or in the earth; alſo about an 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 philoſophizes fooliſhly enough on the attraction of iron, and its turning to the poles. Moſt recently, Baptiſta Porta, 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, 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' 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 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 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 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 has ſung;

ſung; Or as Albertus Magnus teaches, that there are two kinds of 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 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 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, chorus-leader of vanities, teaches: Or that in a loadſtone pickled in the ſalt of a ſucking fiſh 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, 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

as William Borough in his little book on the *Variation of the Compaſs* or Magneticall Needle, William Barlowe in his *Supply*, Robert Norman in his *Newe Attractive*. And this is that Robert Norman (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*.

LOADSTONE, the ſtone which is commonly called the Magnet, derives its name either from the diſcoverer (though he was not Pliny's fabulous herdſman, 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 Aſia 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

them the fineſt 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 inacceſſible 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, 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 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; 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 Georgius Agricola and ſeveral other men learned in metallurgy witneſs.

witneſs. In like 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; 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 ἡράκλιος, as by Theophraſtus, and μαγνῆτις; and μάγνης, as by Euripides, as quoted by Plato in the *Io:* by Orpheus too μαγνῆσα, and σιδερίτης as though of iron: by the Latins *magnes*, *Herculeus;* by the French *aimant*, corruptly from *adamant;* by the Spaniards *piedramant:* by the Italians *calamita;* by the Engliſh **loadſtone** and **adamant ſtone,** by the Germans *magneſs* 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:* Ἔοικε δὲ καὶ Θαλῆς ἐξ ὧν ἀπομνημονεύουσι, κινητικόν τι τὴν ψυχὴν ὑπολαβεῖν, εἴπερ 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), it differs in form: in German *Katzenſilber* and *Talke.*

CHAP.

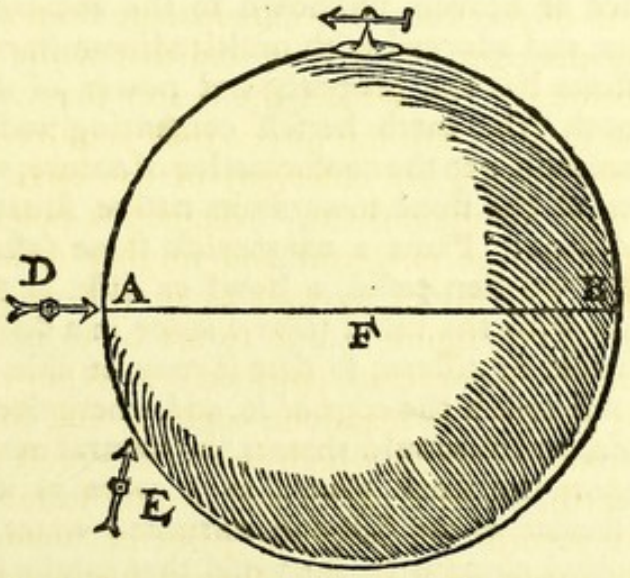
CHAP. III.

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 pre-eminent 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; 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 prepared 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

means of which many abſtruſe and neglected truths in philoſophy buried in piteous darkneſs may more readily become known to men. This round ſtone is called by us a μικρόγη or *Terrella.* 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:



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

centre of the ſtone. For inſtance, the verſorium D faces toward A and F, the pole and centre, whereas E does not exactly reſpect
* either the pole A or the centre F. 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: 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, 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

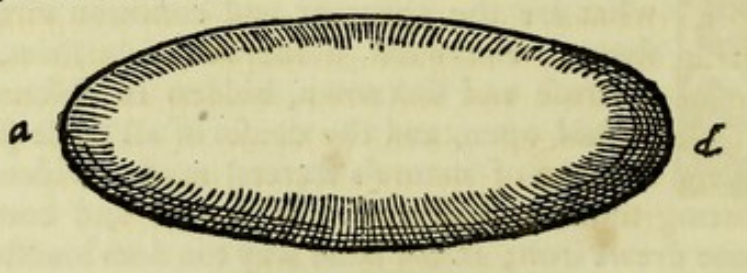
determined goals; and this is ſo, not only if the poles have been diſpoſed in the veſſel evenly with the plane of the horizon, but alſo in the caſe of one pole, whether auſtral or boreal, being raiſed in the veſſel ten, or twenty, or thirty, or fifty or eighty degrees, above * the plane of the horizon, 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.

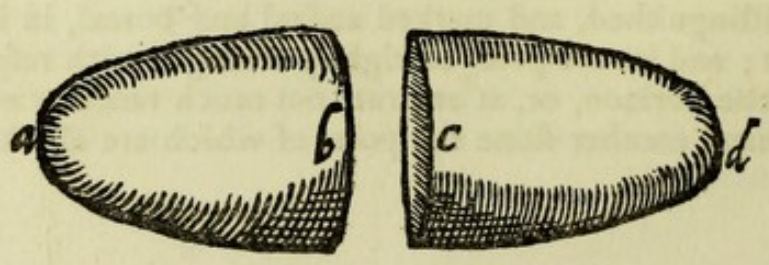
CHAP. V.

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

FIRST 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

ſuch a way that its auſtral 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 load-ſtone (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, ſo as to float.





And

And you will then ſee that A the northern point will turn to the ſouth, as before; in like 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.

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, 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 has been touched with a loadſtone more powerfully than iron that has not been ſo touched.

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 quick-ſilver, 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

things are the reſults of a different nature, they are neither 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

vapours is a more 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.

Here corn exults, and there the grape is glad,
Here trees and graſs unbidden verdure add.
So mark how Tmolus yields his ſaffron 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

in firmneſs and 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 without the ſcales is found in England, which alſo they uſe for craftſmen's ruddle. In Suſſex in England 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 Emerel-ſtone, 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*, "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

"that after being ſimply waſhed it is ſmelted in the furnace; others "declare that it 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, 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

(that 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, pitch-forks, 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 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.

CHAP.

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 (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 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 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*) 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, 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 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;

corded ; for it has never been known to rain from the ſky gold, ſilver, lead, tin, or ſpelter. 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, 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.

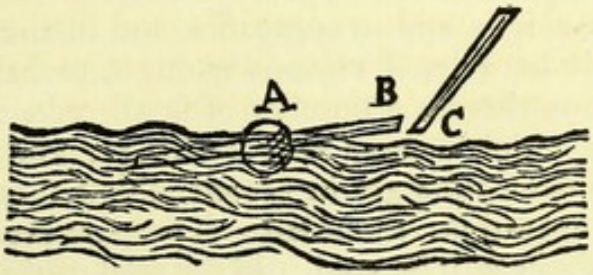
✳ Iron ore has poles, and acquires them, and ſettles itſelf toward the poles of the univerſe.

EPLORABLE 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); 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.

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, 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

end at the diſtance of half a digit. The balanced iron 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

of which you will afterwards find 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. 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.

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

DIOSCORIDES 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 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 foul. 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, 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 have opined 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

look for remedies while ignorant of the true cauſes of things. The application of a 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, juſt as the Augſburgers do into a black plaſter 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.

CHAP. XV.

The Medicinal Virtue of Iron.

OT 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 liver and ſpleen, think it beneficial in thoſe caſes becauſe it removes obſtructions, mainly truſting to the opinions of certain Arabians: 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 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.

many. By Manardus, Curtius, Fallopius and others, many reaſons are adduced on 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 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 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.

CHAP. XVI.

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 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 load-

ſtone,

ſtone, & a weak one which ſcarce can attract a ſingle chip 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; 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

and of the terreſtrial globe; which 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, 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) 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 that is more homogenic, true & cognate with the globe of the earth; leſs infected & 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 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.*

PRIOR 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

experiments & proofs, will be as certainly aſſured as 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, 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 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

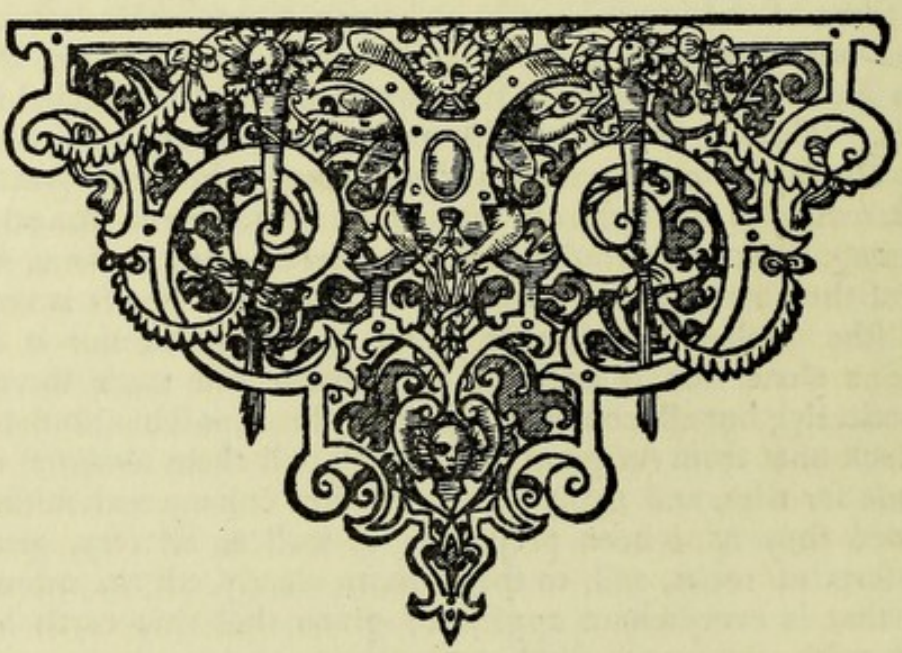
are found by mariners as they ſound the depths. Nowhere does the Ariſtotelian element of *earth* come to light; and the Peripateticks are the ſport of their own vain dreams about elements. Yet the lower bulk of the earth and the inward parts of the globe conſiſt of ſuch bodies; for they could not have 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 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 is *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

inward parts, poſſeſſed of a magnetick homogeneal nature, and upon ſuch more perfect 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, 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

later. Thus every part of the earth which is removed from it exhibits by ſure experiments every impulſe of the magnetick nature; by its various motions it obſerves the globe of the earth and the principle common to both.

BOOK



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 or differences of motions are then obſerved by us: Coition (commonly called attraction), the incitement

citement to magnetick union; Direction towards the poles of 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 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),

Galen), deſiring to confirm the belief in the attraction of purgative medicines by 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, becauſe it attracts ſtraws to itſelf, when it is warmed by rubbing; then it is called ἄρπαξ; and χρυσοφόρον, from its golden colour. But the Moors call it Carabe, 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. The Sudavienſes or Sudini 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. The ancients and alſo more recent writers recall (experience proving the ſame thing), that amber attracts ſtraws and chaff. The ſame is alſo done by jet, 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 who have written and copied from others about amber and jet attracting chaff, and about other ſubſtances

ſtances generally unknown; with whoſe labours the ſhops of book-ſellers 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; but Diamond, Sapphire, Carbuncle, Iris gem, Opal, Amethyſt, Vincentina, and Briſtolla (an Engliſh gem or ſpar), Beryl, and Cryſtal 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 compounded of lac tinctured of various colours. Rather hard reſin entices, as does orpiment, but leſs ſtrongly; with difficulty alſo and indiſtinctly under a ſuitable dry ſky, 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, 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, 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, and what thoſe materials 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

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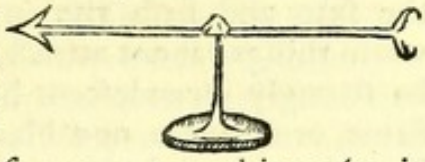
and poliſhed gem which has been gently rubbed; for the verſorium turns forthwith. Many things are thereby ſeen to attract, both thoſe which are formed by nature alone, and thoſe which are by art prepared, fuſed, and mixed;



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 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 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

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ill-conſidered views; for towards all electricks all things move 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, 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, which has been concreted from clear water, not always

always by a very great cold, as ſome uſed to 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, 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. 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

moſtly reſtrained, as it were, within certain barriers; and therefore that force muſt at times be aroufed 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 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 aroufed by means of a * burning mirror confers no vigour on the heated amber; 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

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in the caſe of certain ſubſtances 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*: 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, 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 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 ſtopped 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

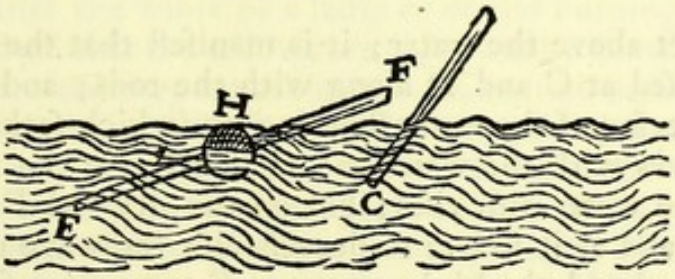
effluvia

effluvia produce a rarefied medium, and on that account bodies are more prone to ſlip 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; 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

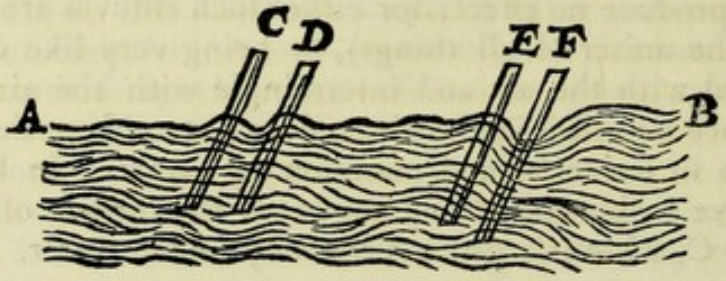
and other ſubſtances of that kind, when they are rubbed, produce no effect. Is there not alſo ſomething which is exhaled from them by heat and attrition? Moſt truly; but from groſſer bodies more blended with the earthy nature, that which is exhaled is groſs and
* ſpent; for even towards very many electricks, 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

the opinion of Pythagoras, is the principle of 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 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 ver-
* ſorium 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 ſtrives to depreſs alſo the wave riſing on E in its neighbourhood, the higher wave at E turns away from F; 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

book *Spiritalia*), then the effluvium 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 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 ſet 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 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

is not changed by heat, but which is its own, cauſes union and cohærency, 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, 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 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. 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

and the more modern writers. Orpheus in his hymns 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 re-"bound 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 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 con-"gregated together, they all paſs, each to its proper ſeat, but with "changed places; and it is, forſooth, on account of theſe inter-"complicated 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:

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

Such a reaſon Plutarch alſo alleges in the *Quæſtiones Platonicæ;* That that ſtone gives off heavy 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. 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 ſeek-"ing 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

But that is a chilly ſtory, and worſe than an old woman's tale. So alſo is the 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., 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 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 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 com- "pany 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 con- ſpiracies in the ſtone, as if it were nurſing up perpetual quarrels, whence

whence it might ſeek auxiliary forces, are the ravings of a babbling old 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 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 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 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.

CHAP. IIII.

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

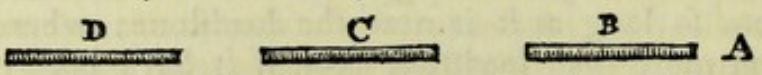
force penetrates even to the other extremity, not through its ſurface only, but through the interior and all through the middle. Electrical bodies have material and corporeal effluvia. Is any ſuch magnetical effluvium given off, whether corporeal or incorporeal? or is nothing at all given off that ſubſiſts? 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

longiſh ſtay in the fire, loſes the powers of attracting implanted and innate in it, and 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 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 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

perfect and homogeneous parts of the ſpheres of the univerſe to the whole, and a mutual 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 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; 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

have 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 load- *
ſtone, 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 load- ſtone, 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

approach as ſoon as they have entered within the orbe of 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

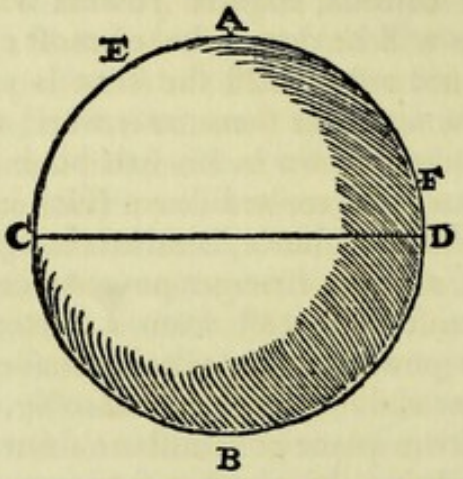
D the forces by which D is taken and conformed, though they are weaker than thoſe which C receives from B. And thoſe iron nails indeed from that contact only, and from the preſence of the loadſtone even without contact, acquire powers which they retain in their own bodies, as will be demonſtrated moſt 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. 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 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.

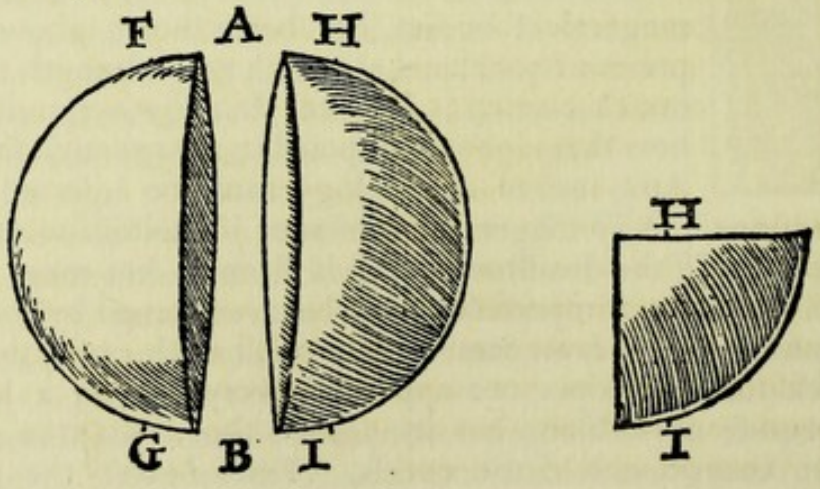
How the Power dwells in the *Loadſtone*.

THAT 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

ſtronger, thoſe far away more 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.

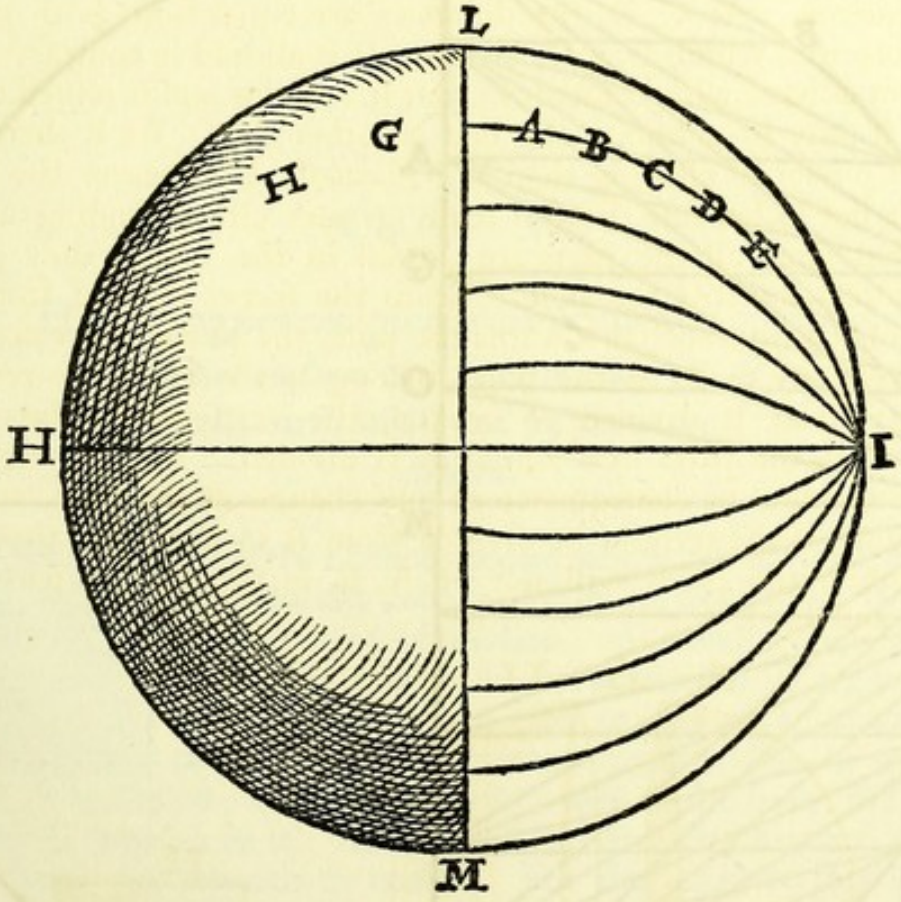


At C and D there is no force alluring magnetick ends to the body, for the forces tend toward both poles. But direction is powerful on the æquator. At C, D, the diſtances are equal from both poles; therefore iron which is at C, D, when it is allured in contrary ways, does not adhære with conſtancy; but 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.



Theſe

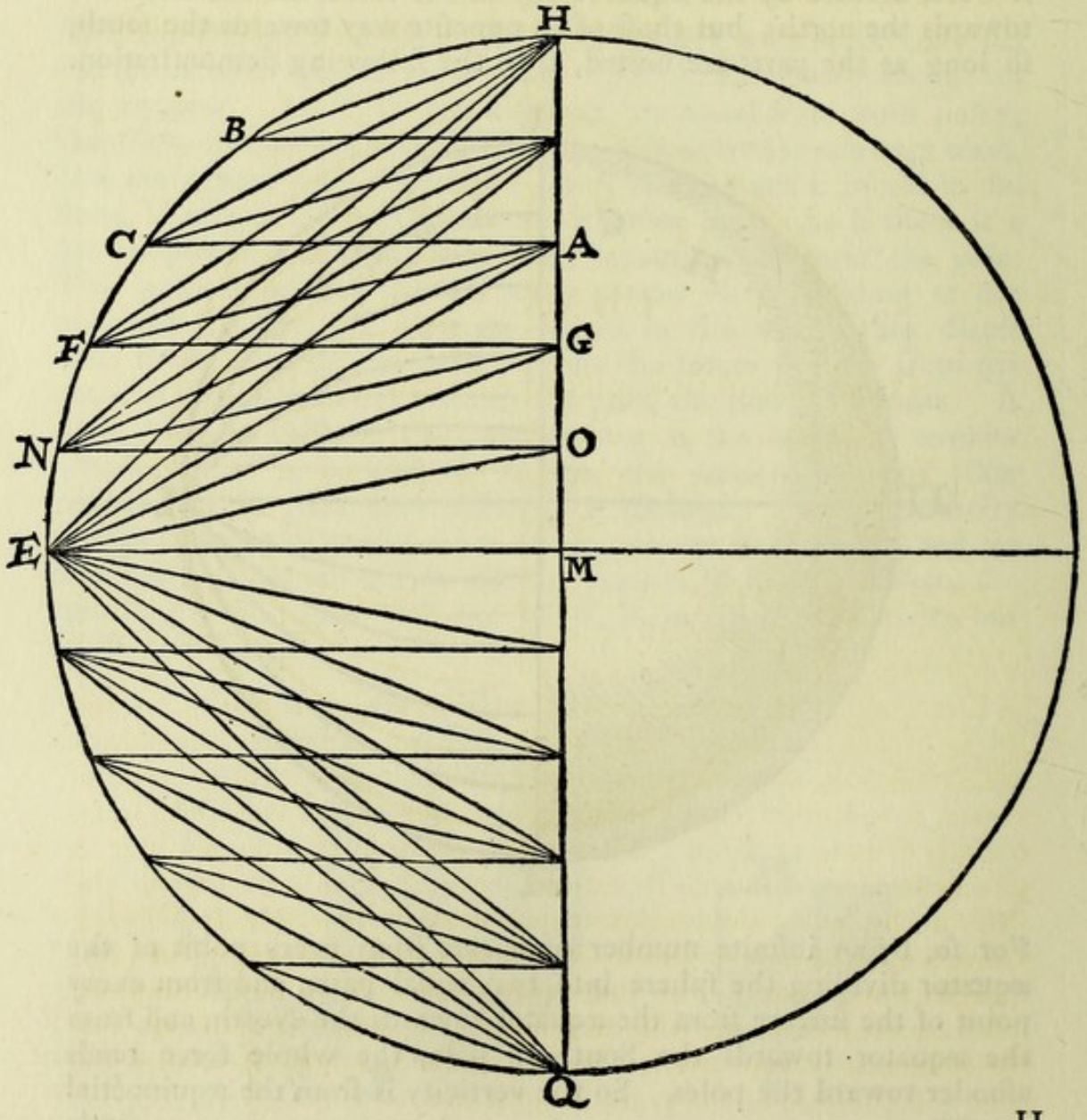
Although theſe ſtones now are in agreement with one another, ſo that F would not ſeek H, yet if A was previouſly the boreal pole, F is now boreal, and H alſo boreal; for the verticity is not changed (as Baptiſta Porta incorrectly affirms in the fourth chapter of his ſeventh book); ſince, though F and 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, 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.



For ſo, by an infinite number of curves from every point of the æquator 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.

Diagram of Magnetick Vigour,
tranſmitted from the plane of the Æquator
to the periphery of the terrella,
or of the earth.



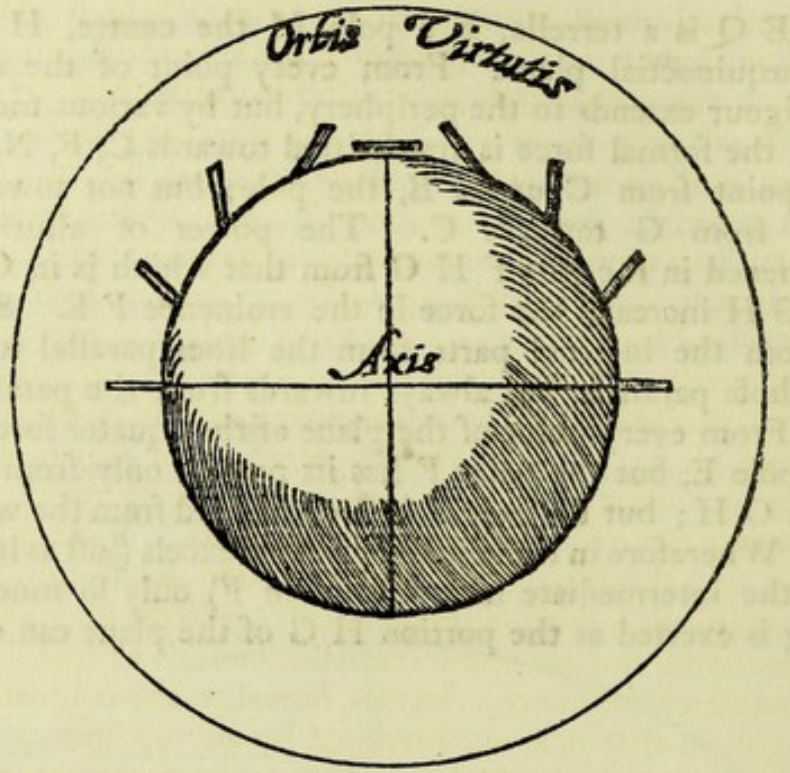
HE Q is a terrella, E a pole, M the centre, H M Q the æquinoctial plane. From every point of the æquinoctial plane vigour extends to the periphery, but by various methods; for from A the formal force is tranſmitted towards C, F, N, E, and to every point from C up to E, the pole; but not towards B; ſo neither from G towards C. The power of alluring is not ſtrengthened in the part F H G from that which is in G M F E, but F G H increaſes the force in the eminence F E. 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 G H, and N from O H; but the pole E is ſtrengthened from the whole plane H Q. 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 H G of the plane can contribute.

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.

The



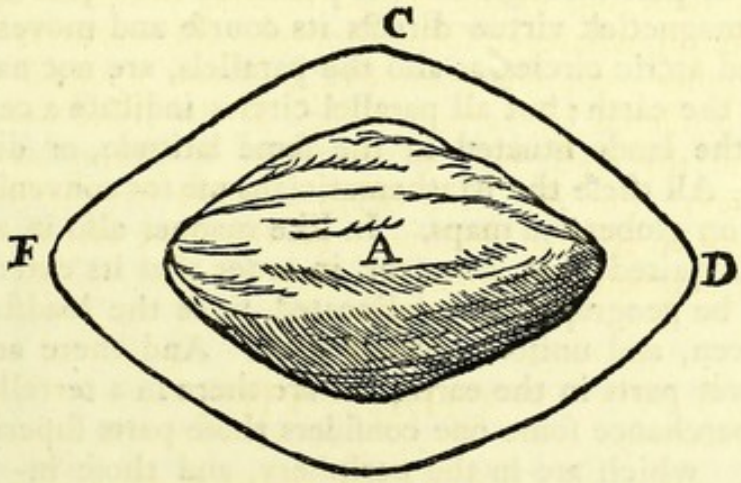
The nearer the parts are to the æquinoctial, the more obliquely are magneticals allured; but the parts nearer the poles appeal more directly, at the poles quite ſtraight. The principle of the turning of all loadſtones, of thoſe which are round and thoſe which are long, is the ſame, but in the caſe of 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

only excites magneticks at a convenient diſtance from it. And as light comes in an inſtant (as the opticians teach), ſo much more 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.

CHAP.

CHAP. VIII.

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 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.

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.

CHAP.

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.

On the Axis and Magnetick Poles.

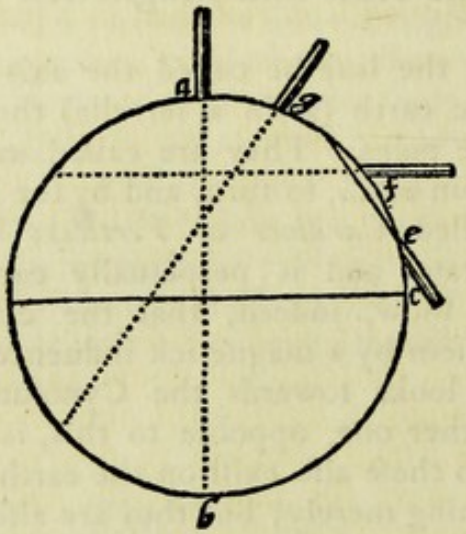
LET the line be called the axis which is drawn in the earth (as in a terrella) through the centre to the poles. They are called πόλοι by the Greeks from πολεῖν, to turn, and by the Latins they are alſo called *Cardines* or *Vertices*; becauſe the world rotates and is perpetually carried around them. 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 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.

CHAP. XV.

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.*

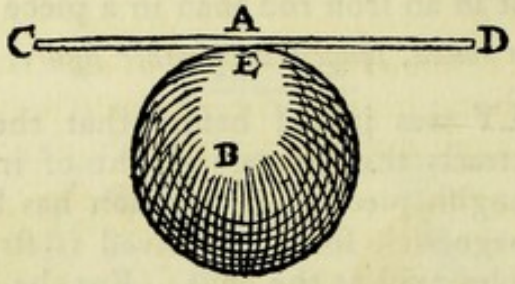
DULY was it ſaid before that the longer magnet attracts the greater weight of iron; ſo alſo in a longiſh piece of iron which has been touched the magnetick force conceived is ſtronger when the poles exiſt at the ends. For the magnetick forces which are driven from the whole in every part into the poles 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.

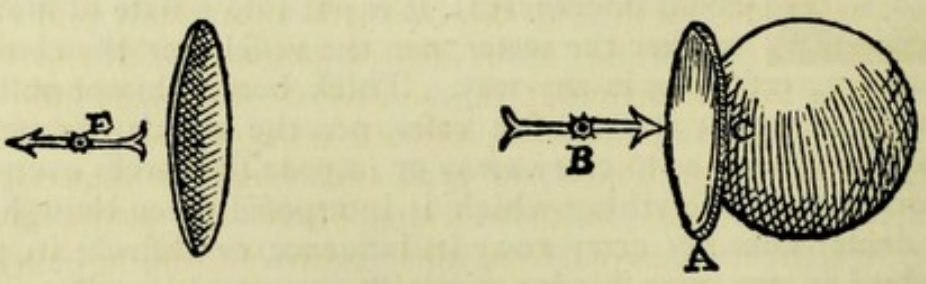
Showing that Movements take place by the Magnetical Vigour though ſolid bodies lie between; and on *the interpoſition of iron plates.*

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, 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

oppoſite the pole of the ſtone, that virtue is ſcattered in very large
* meaſure towards its 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.

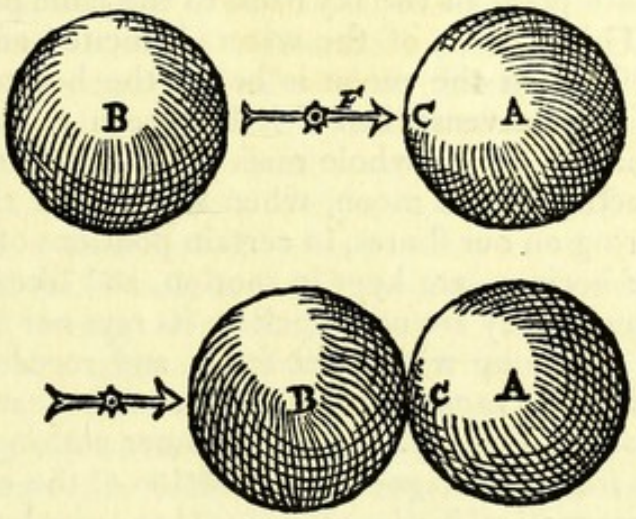


B is a loadſtone, C D a long rod magnetized in the middle A; E being the Boreal pole; C is an Auſtral end or pole; in like manner alſo the end D is another Auſtral pole. But obſerve here the exactneſs with which a verſorium touched by a pole, when a
* round plate is interpoſed, turns towards the ſame 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

placed outſide the orbe of magnetick virtue, the point will not turn towards its centre, 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 with one another. But in the caſe of all thoſe ſubſtances which have a material cauſe for their inclining (as amber,

jet,

jet, ſulphur), their action is impeded by the interpoſition of a body (as paper, leaves, glaſs, or the like) when that way is impeded and obſtructed, ſo that that which exhales 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 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; 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.*

CONCEIVE 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

when two loadſtones, armed with iron caps, are ſo joined by their 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 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; 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 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.*

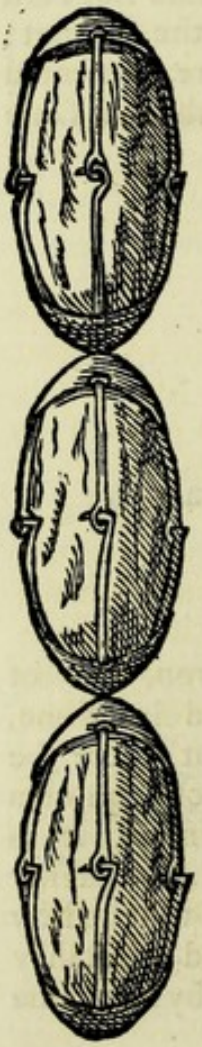
SUPPOSE there are two pieces of iron, one of * which has been excited by an armed loadſtone, the other by one unarmed; and let there be applied to one of them another piece of iron of a weight juſt proportional to its ſtrength, it is manifeſt that the remaining one in like manner raiſes the ſame and 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.

CHAP.

CHAP. XIX.

Union with an armed Loadſtone is ſtronger; *hence greater weights are raiſed; but the* coition is not ſtronger, but gener- *ally 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.

An armed Loadſtone raiſes an armed Load- *ſtone, 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 adhæres and in the caſe of robuſt ſtones, a fourth to the third.

CHAP. XXI.

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.

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. 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

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.

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

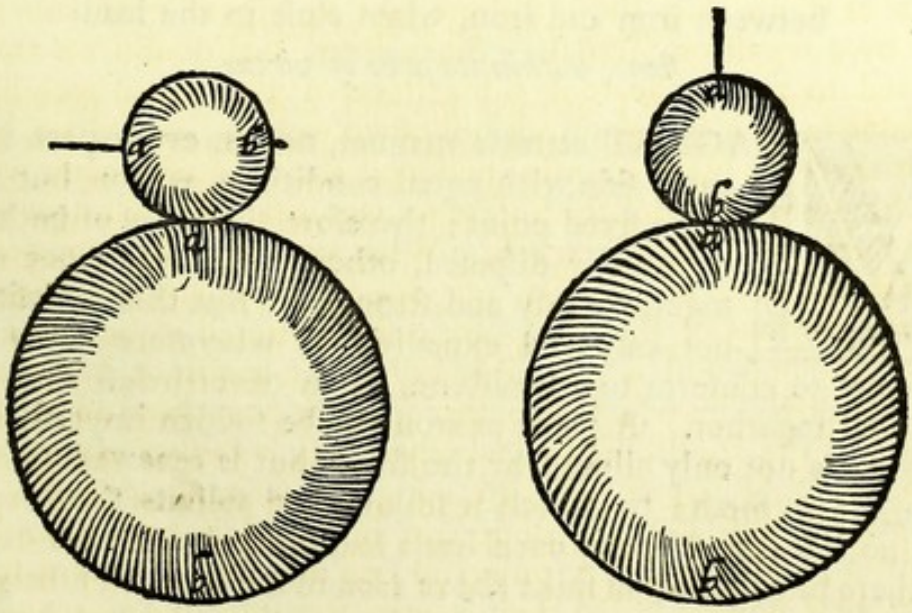
always the ſtronger the nearer it is. So that when a piece of iron is raiſed a very little from the earth by the force of the magnet, it needs muſt be drawn ſteadily on towards the magnet (if nothing elſe come in the way) and cleave to it. Baptiſta Porta ſuſpends a piece of iron in the air (a magnet 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

they eat and are ſated? Is the medicine prepared by addition or ſubtraction? Is there 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 load-"ſtone." 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

the boreal pole becomes 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 load- *ſtone, 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

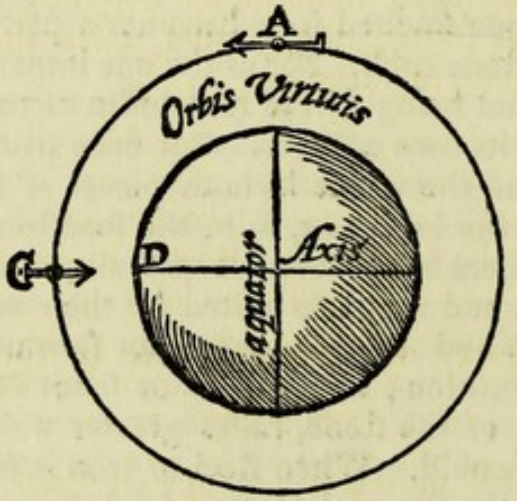
ſo that it touches the ſtone, you will ſee the ſpike when it has touched the iron, leaving the loadſtone, follow the rod, try to graſp it by leaning toward it, and (if it ſhould touch it) cleave firmly to it: for a piece of iron, when united and joined to another piece of iron placed within the orbe 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

power of the ſtone and of the earth does not promote anything but the unity 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

is made on every part of the periphery, both 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, 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 propor-

tion and would draw it towards itſelf with no greater effort of its nature or trouble 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.*

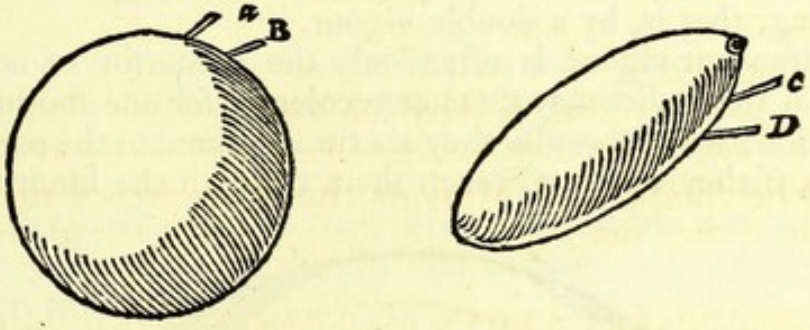
OBSERVATION has ſhown above that the ſhape and maſs of the loadſtone have great influence in magnetick coitions; likewiſe alſo the ſhape and maſs of the iron bodies give back more powerful and ſteady forces. Oblong iron rods are both drawn more quickly to a loadſtone and cleave to it with greater obſtinacy 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.

CHAP. XXXI.

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, 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.*

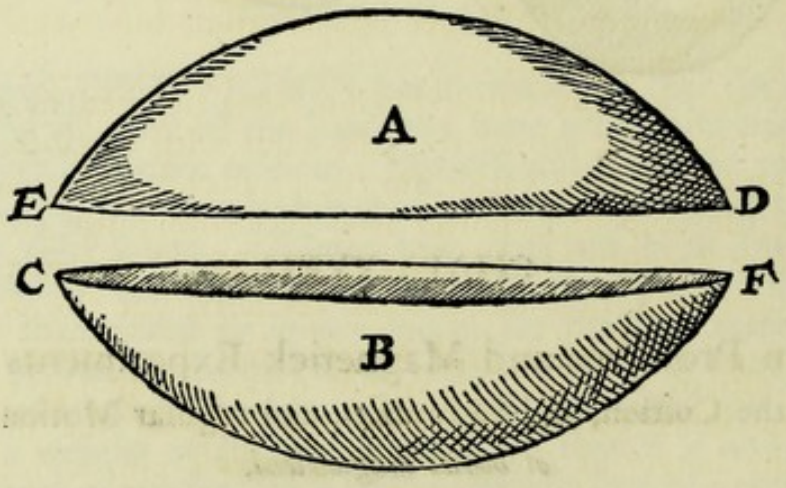
EQUAL loadſtones come together with equal incitation. *
Alſo magnetick bodies of iron, if alike in all reſpects, come together when excited with ſimilar incitation. * *

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

able ſkiffs, if they are drawn up 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] 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 mag-

magnetical; but in proximity they raiſe enmities. But if 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 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, "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 con- "trary 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.

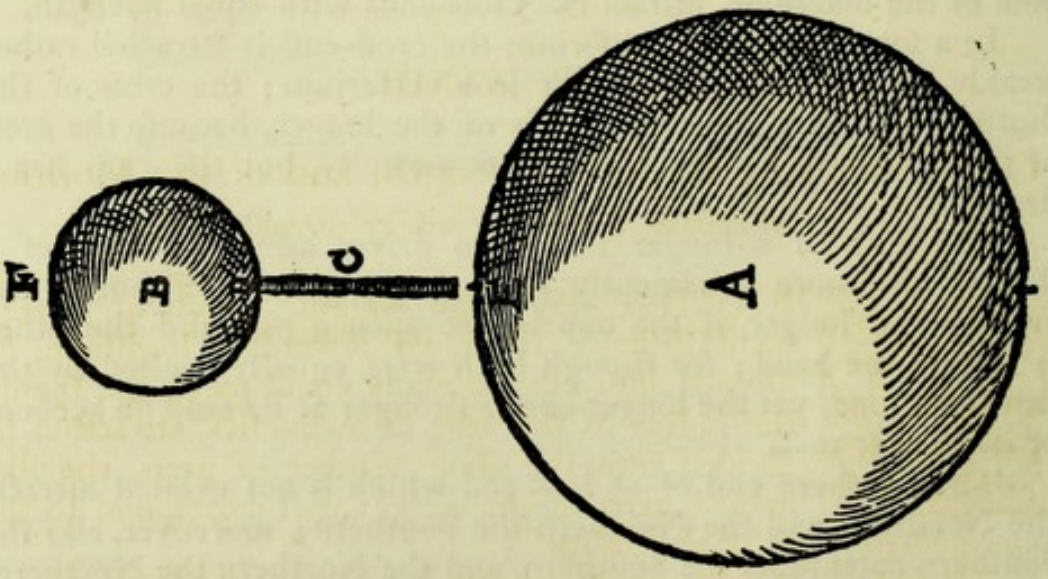
* The ſeparate parts aſſume two oppoſite poles, if the diviſion has not been made along a parallel: if the diviſion has been made along a parallel, they are able to retain one pole in the ſame ſite as before.

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

its conjunction with the terrella. The end that is turned away alſo conceives vigour from the 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 diveſted 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

by the loadſtone being brought nearer. A ſmall verſorium alſo is turned when a good 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.

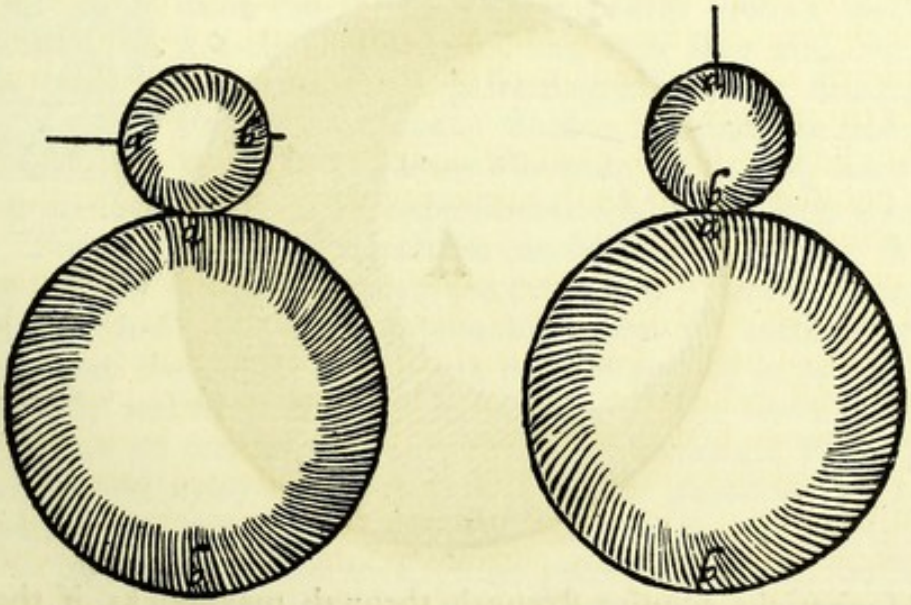
But if there is a loadſtone beneath the paper, the maſs is ſplit in the ſame way and many portions reſult, each of which conſiſts of very many parts, and remains cemented together, as individual bodies. Whilſt the lower parts of theſe purſue greedily the pole of the loadſtone placed directly beneath, 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.

CHAP. XXXIIII.

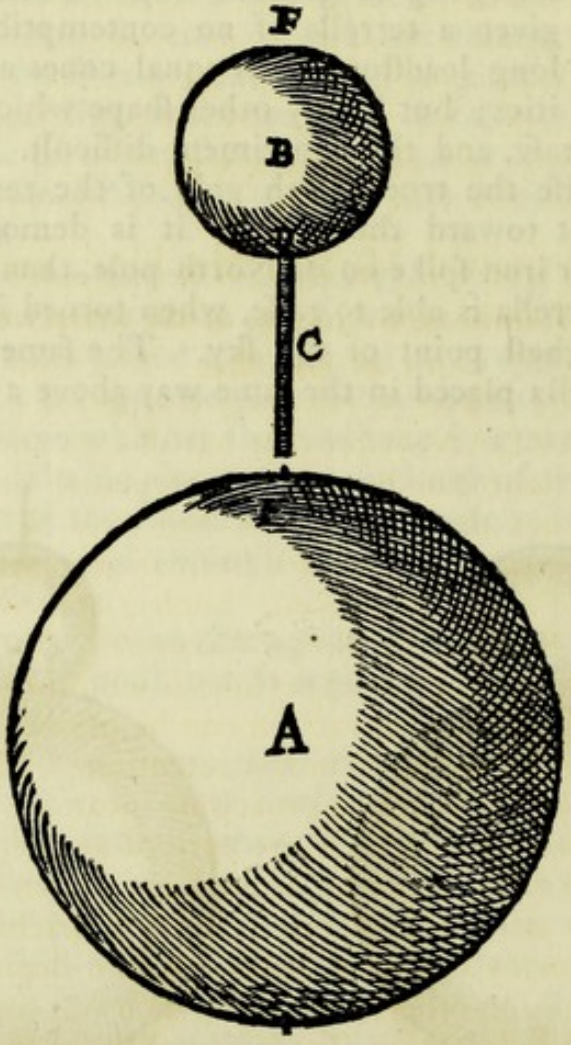
Why a Loadſtone ſhould be ſtronger in its poles in a different ratio; as well in the Northern *regions as in the Southern.*

THE 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 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

its 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 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, 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.

CHAP. XXXVI.

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 æquilibrium, 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*, 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, ſettle more tardily, adhære more uncertainly, and are eaſily diſturbed from their poſſeſſion.

CHAP. XXXVII.

Uſe of a Loadſtone as it affects *iron.*

BY magnetick coition we teſt iron ore in a black-ſmith'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* 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.

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 of 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

mate natural bodies do not 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, 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 there-
"fore" (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 any-
"one 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

ſucking fiſh tarry, and the neceſſity of ſome vacuum, I know not what, or how produced. Pliny and Julius Solinus make mention of a ſtone Chatochitis. 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, of the colour of a ſard, is a precious ſtone mentioned by Pliny, Solinus, Albertus, and Evax; 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 flows 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

or bears the fire for ſuch a convenient 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 quick-ſilver draws metals by reaſon of an occult property, juſt as a load-ſtone 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

attracting one another. Animals take food (as 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 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. 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. 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.

BOOK

BOOK THIRD.

CHAP. I.

ON DIRECTION.

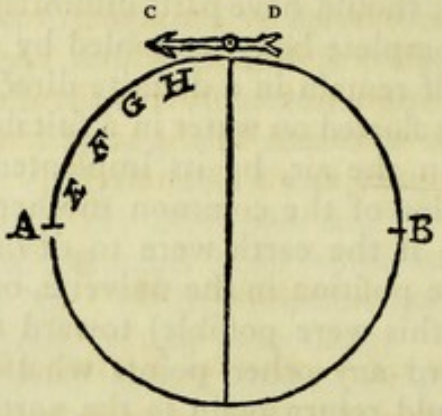
ON referring to the earlier books it will be found ſhown that a loadſtone has its poles, and that a piece of iron has alſo poles, and rotation, and a certain verticity; finally, that the loadſtone and the iron direct their poles toward the poles of the earth. Now, however, we muſt make clear the cauſes 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, 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

toward the true poles of the world, do not 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,

poſition, condition, verticity, poles, æquator, horizons, meridians, centre, circumference, 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, 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

orbicular ſtone, whoſe poles are A and B; an iron wire C D, which is placed upon the ſtone, always points directly along the meridian toward the poles A B, 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 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, 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

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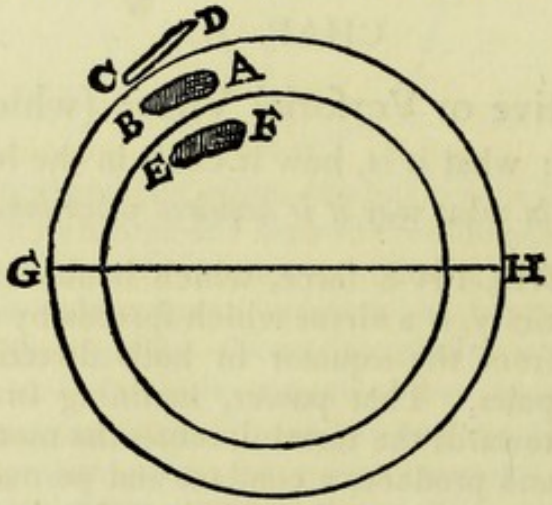
to both, and that in all magnetick ſubſtances there is attraction and repulſion. For both the ſtone and the magnetick iron arrange themſelves by inclination and declination, according to the common poſition of their nature and the earth. And the force of the earth by the virtue of the whole, by attracting 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.

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.*

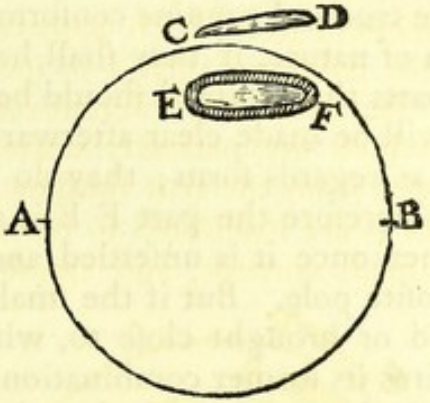
DIRECTIVE force, which is alſo called by us verticity, is a virtue which ſpreads by an innate vigour from the æquator in both directions toward the poles. That power, inclining in both directions towards the termini, cauſes the motion of direction, and produces a conſtant and permanent poſition in Nature, 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

turn to the north on the waves and at length ſettled toward that 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 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

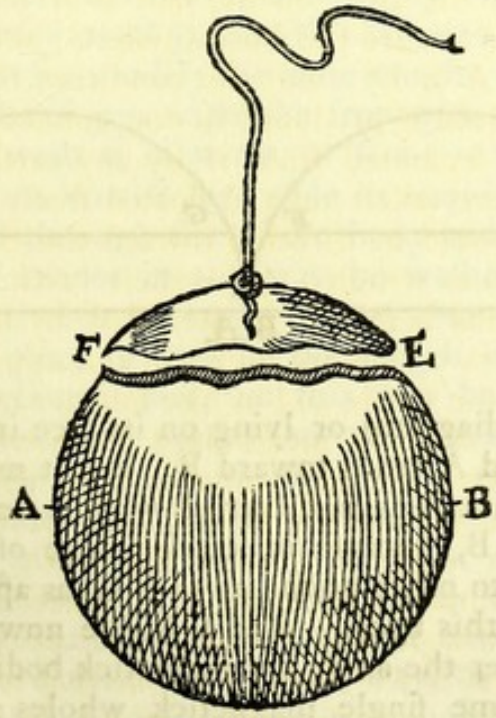


piece of magnetick ore; between which and the uniform globe of the earth lie various ſoils or mixtures which ſeparate the ore to a certain extent from the globe of the true earth. It is therefore influenced by the forces of the earth juſt in the ſame way as C D, a piece of iron, in the air. So the face 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 it 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

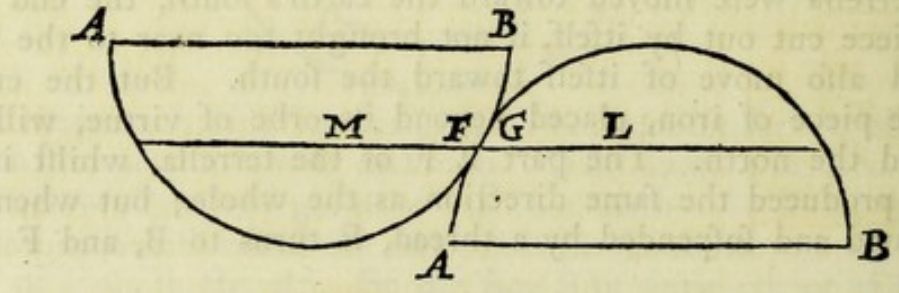
following demonſtration, and comes about of neceſſity according to all magnetick laws. Let there be a terrella with poles A B; from its

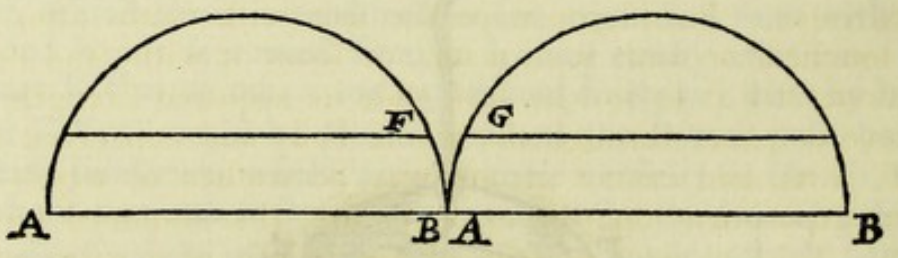


maſs cut out a ſmall part E F; if this be ſuſpended by a fine thread above the hole or over ſome other place, E does not ſeek the pole A but the pole B, and F turns to A; very differently from a rod of iron C D; becauſe C, touching ſome northern part of the terrella, being magnetically carried away makes 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 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

vertices in accordance 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.*

FRICTION between an oblong piece of iron and a loadſtone imparts to the former magnetick virtues, which are not corporeal nor inhærent 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

ſtrength, or becauſe the whole iron was not heated to redneſs, for the virtue is 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 load-
* ſtone 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 un-ſettled 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

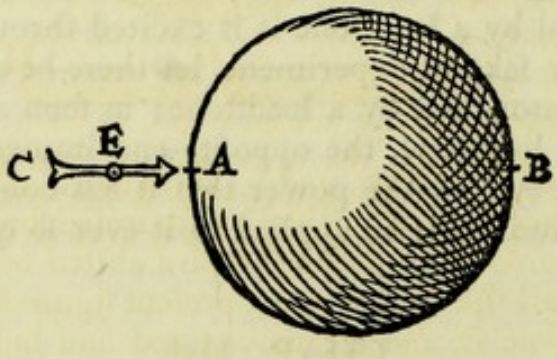
ſtronger. But when the iron is ſeparated from contact with it, then it becomes much weaker, eſpecially in the end that was not touched. Juſt as a long rod, one end of which is placed in the fire and heated, grows exceedingly hot at that end, leſs ſo in the parts adjoining and in the middle, whilſt at 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.

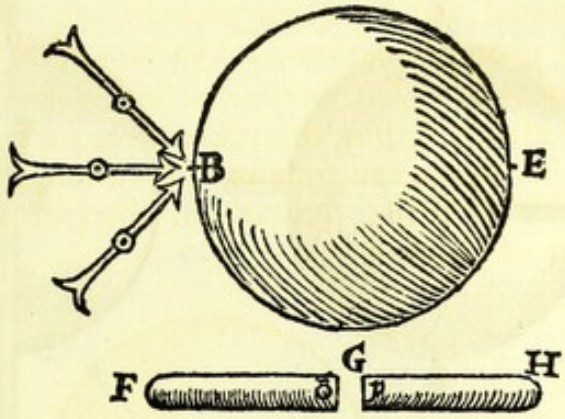
Why Iron touched by a Loadſtone acquires an oppoſite *verticity, and why iron touched by the true Northern ſide of a ſtone* turns to the North of the earth, by the true Southern ſide *to the South; and does not turn to the South when rubbed by the Northern point of the ſtone, and when by the Southern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

DEMONSTRATION 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 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 con- * formed 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

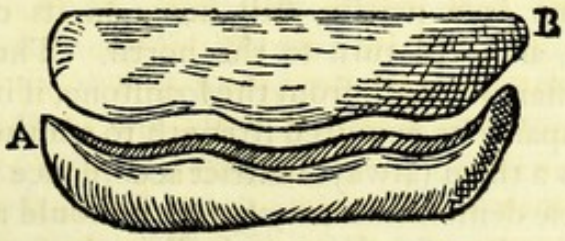
pole of the earth to which that pole of that loadſtone turned by which it was excited. It has been pointed out that iron and loadſtone are of one primary nature; when the iron is joined to the loadſtone, they become, as it were, one body, and not only is the end of the iron changed, but the remaining 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

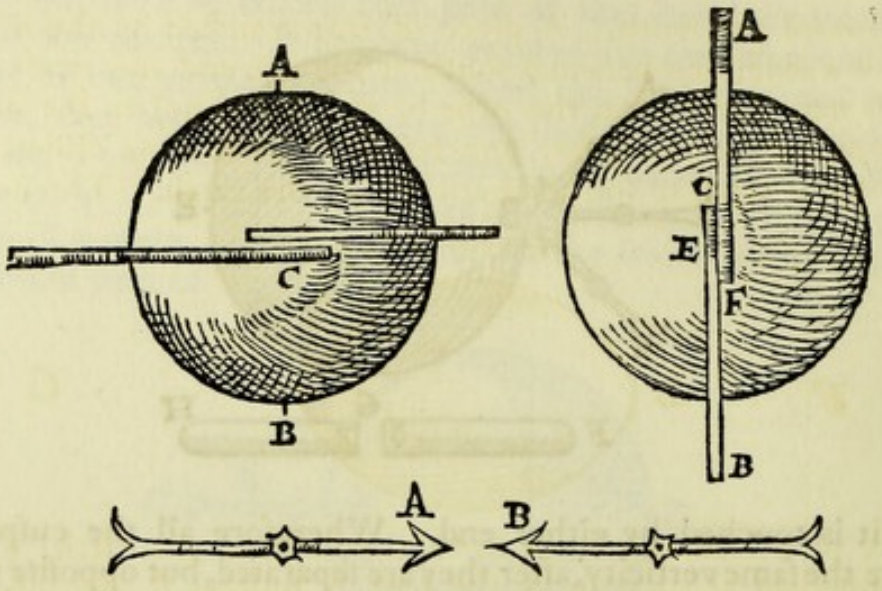


vided it is touched by either end. Wherefore all the cuſps at B acquire the ſame verticity, after they are ſeparated, but oppoſite to that pole of the ſtone; wherefore alſo they are united to the loadſtone at the pole B; and all the croſſes in the preſent figure have the oppoſite verticity to the pole 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



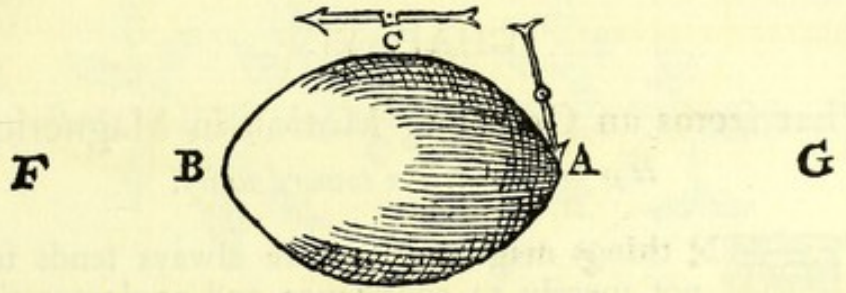
A, until, being turned round, they are connected and cemented together; becauſe magnetick attraction is not made along the parallels, but meridionally. For this reaſon pieces of iron placed on a terrella whoſe poles are A B, near the æquator along parallels, * do not combine or ſtick together firmly:

But



* But if applied to one another along 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) 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

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, 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, 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,

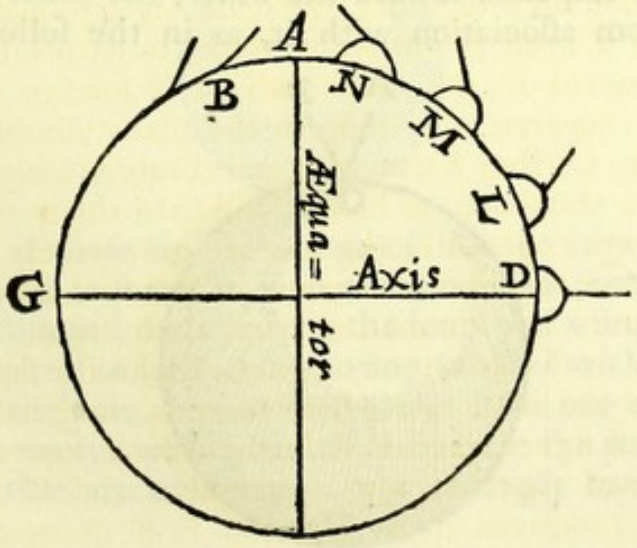
in which C tends to B, the north of the earth, and D to the ſouth, A. Then divide it in the middle in its æquator, and it will be E that is tending toward A, and F tending toward B. For juſt as in the undivided body, ſo in the divided, nature aims at theſe bodies
* being united; the end E again joins 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

this way to the poles of the earth and 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 pruner'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 a ſtrongiſh coition or unition.*



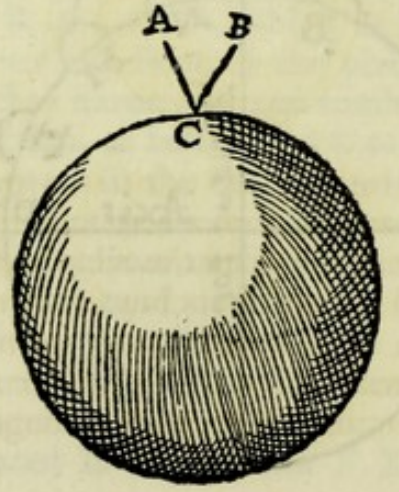
In

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 that is very small and of no weight, 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 perpen-
* dicular, which would happen if the verticity aroſe on account of a ſtronger attraction, or rather coition or unition.

CHAP. VIII.

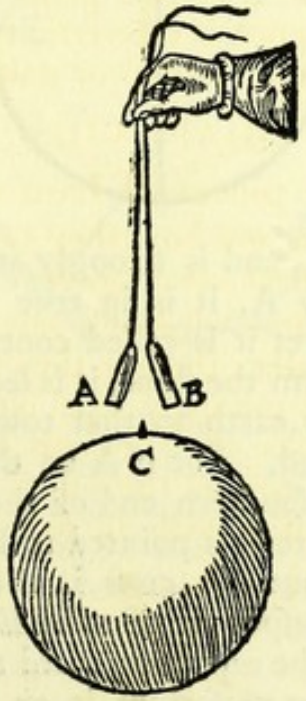
Of Diſcords between pieces of Iron upon the ſame pole of a loadſtone, and how they can agree and *ſtand joined together*.

SUPPOSE two iron wires or a pair of needles ſtuck on the pole of a terrella; though they ought to ſtand perpen-
* dicularly, 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

A and B, iron ſpikes, adhære obliquely 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 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.



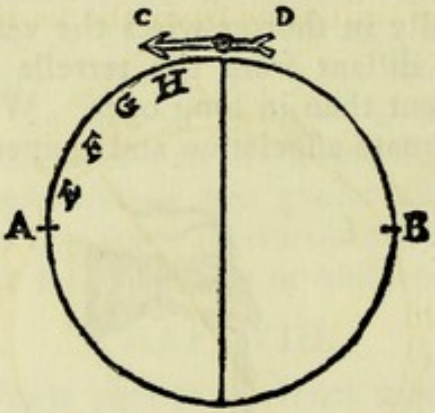
Likewiſe if thoſe lighter pieces of iron or iron wires be ſuſ- pended, hanging, as A and B, from a very fine ſilk thread, not twiſted * but braided, diſtant from the ſtone the length of a ſingle barleycorn, then the oppoſing ends, A and B, being ſituated within the orbe of virtue above the pole, keep 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.

CHAP. IX.

Figures illuſtrating direction and ſhowing varieties *of rotations.*

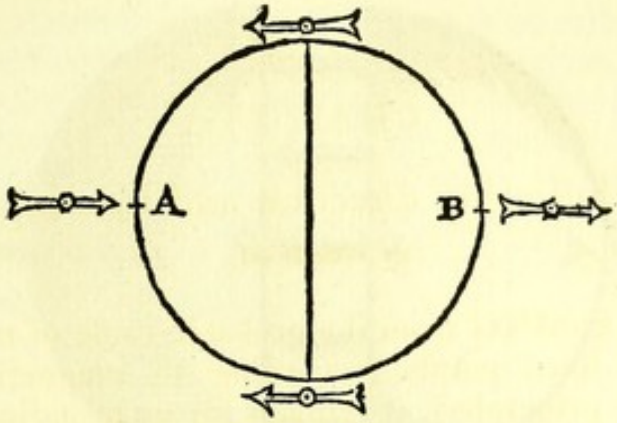
PASSING from the probable cauſe of motion toward fixed points (according to magnetick laws and principles), it remains for us to indicate thoſe motions. Above a round loadſtone (whoſe poles are A, B) let a verſatory needle be placed whoſe cuſp has been excited by the pole A; that cuſp is cer-



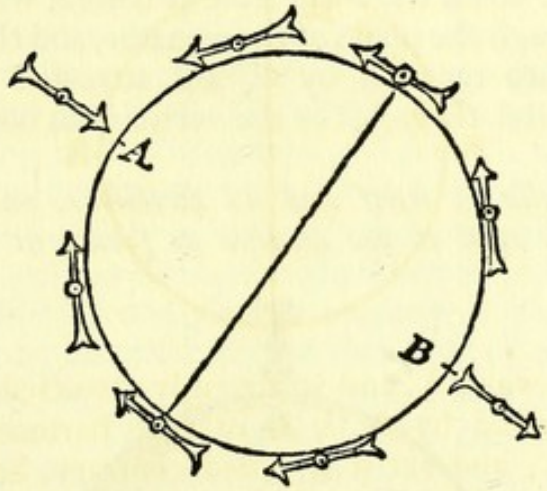
tainly directed toward A, and is ſtrongly attracted by A; becauſe, having been touched by A, it is in true harmony with A, and combines with it; and yet it is called contrary, becauſe when the verſorium is ſeparated from the ſtone, it is ſeen to be moved toward the oppoſite part of the earth to that 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 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.

Figures

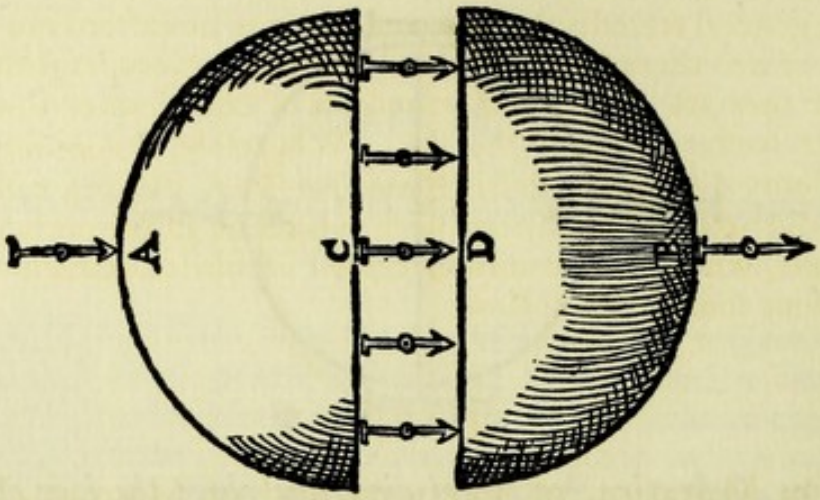


Figures illuſtrating horizontal directions above the body of a loadſtone. All the cuſps that have been made ſouthern by rubbing on the boreal pole, or ſome place round the northern pole A, turn toward the pole A, and turn away from the ſouthern pole B, toward



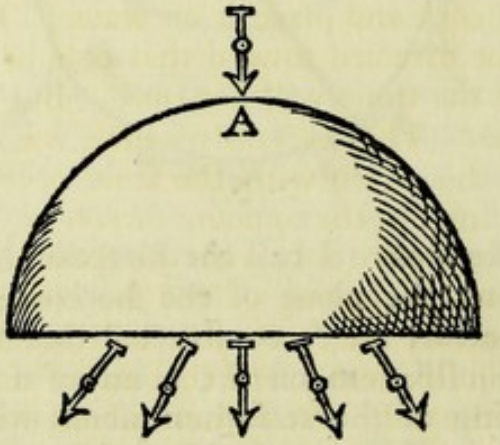
which all the croſſes look. I call the direction horizontal, becauſe it is arranged along the plane of the horizon; for nautical and horological inſtruments are ſo conſtructed that the iron hangs or is ſupported in æquilibrium on the point of a ſharp pin, which prevents the dipping of the verſorium, 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



are directed as in the preſent diagram. 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

as in the general 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.*

FRICTION 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 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 inter-

mediate lamina is not touched either by the 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.*

SELECT 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.

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

HAVING thus far 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

preſerves its verticity, and whence is it derived? So take this firſt from the above 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 or 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 it 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 ſouth, 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 again in the contrary poſition, and let it be placed ſo at a red heat until 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

the end which formerly looked toward the north now turns to the ſouth. In 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 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 load-"ſtone. 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

from our city 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, 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

the touch of a loadſtone; for the magnetick vigour has no entrance into their 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.

CHAP.

CHAP. XIIII.

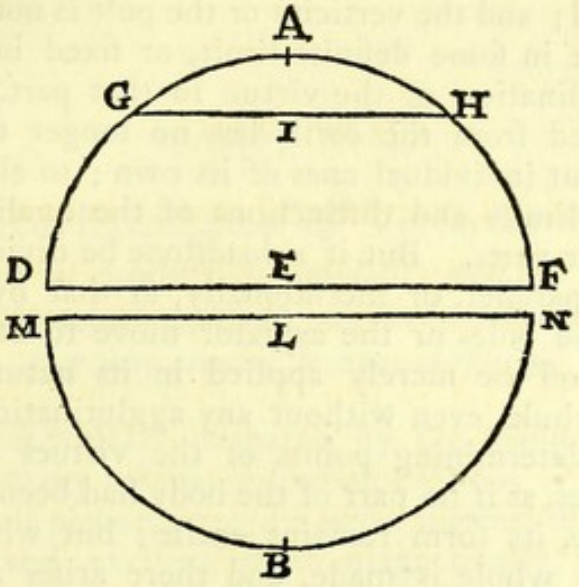
The Placing of a Loadſtone above or below a magnetick body ſuſpended in æquilibrium changes neither the power *nor the verticity of the magnetick body.*

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 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.

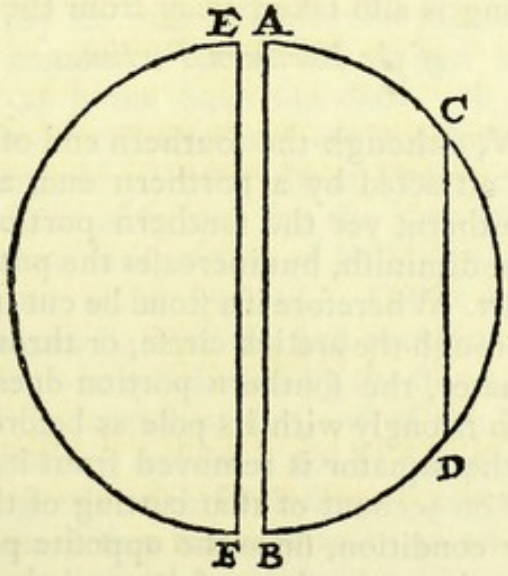
CHAP. XV.

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



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 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; 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.

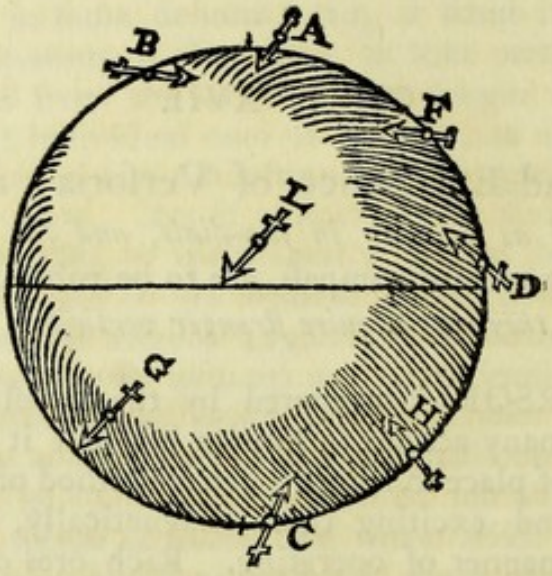
CHAP.

CHAP. XVII.

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.

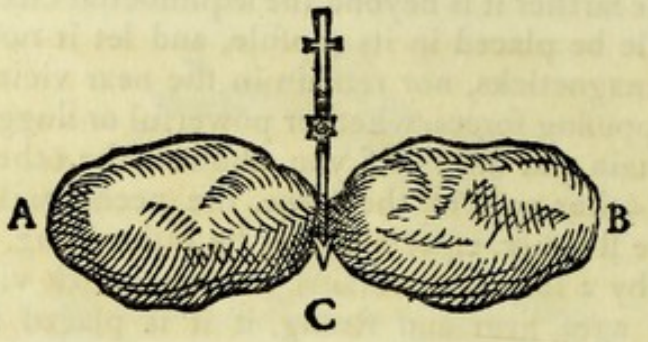
When iron is to be quickened by the ſtone, let it be clean and bright, disfigured by no ruſt or dirt, and of the beſt ſteel. Let the ſtone itſelf be wiped dry, and let it not be damp with any moiſture, but let it be filed gently with ſome ſmooth piece of iron. But the hitting of the ſtone with a hammer 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



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 æquilibrium in the plane of the horizon, now when touched and excited dips at one end, as far as the upright pin on which 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 æquilib-
* rio after it is touched. But a needle in this way prepared does its work

work worſe the farther it is beyond 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, 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



is acquired by the needle. A and B are two loadſtones 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.

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

(obſerved by means of inſtruments or a nautical variation compaſs) is therefore the arc of the horizon between the common point of interſection of it with the true meridian, and the terminus of the deflection 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 ter-

* minus 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

Marſilius Ficinus about a ſtar in the 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; 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; 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

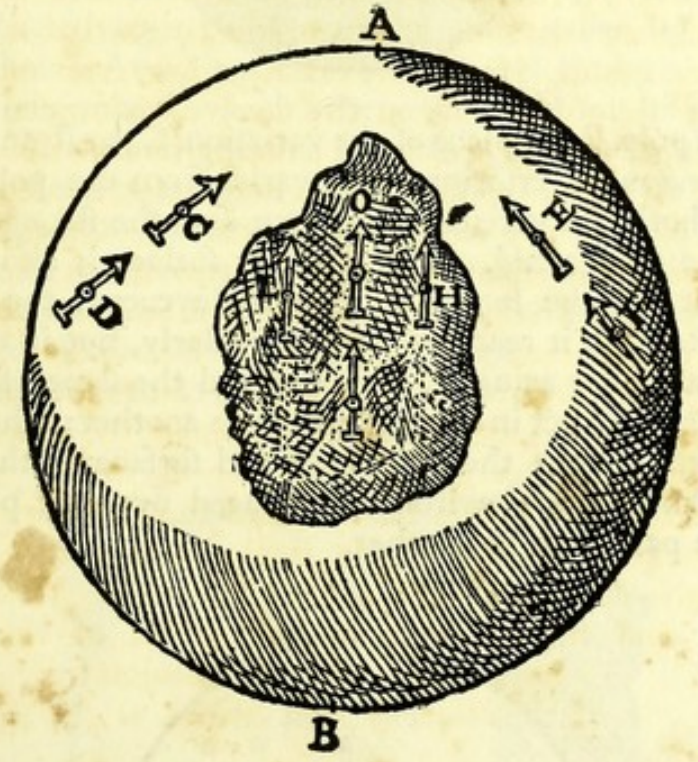
thence along the coaſts of Spain, France, England, Belgium, Germany, Denmark, and Norway, there lie on the right hand and toward the eaſt a continent and extenſive connected regions, and on the left extenſive ſeas and a vaſt ocean lie open far and wide, it is conſonant with the theory (as has been carefully 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.

CHAP.

CHAP. II.

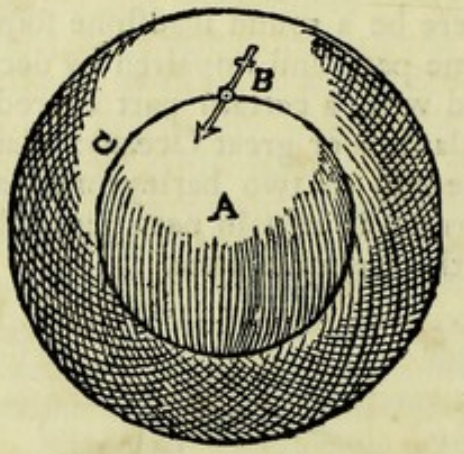
That the variation is cauſed by the inæquality of the *projecting parts of the earth.*

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.

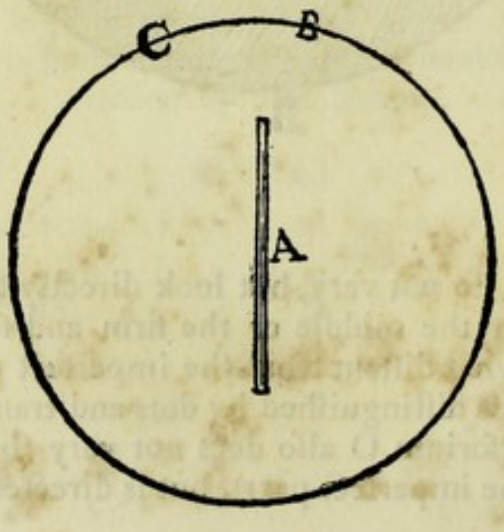


The verſoria E, F, do not vary, but look directly to the pole A; for they are placed in the middle of the firm and ſound part of the terrella and ſomewhat diſtant from the imperfect part: that part of the ſurface which is diſtinguiſhed by dots and tranſverſe lines is the weaker. The verſorium O alſo does not vary (becauſe it is placed in the middle of the imperfect part), but is directed toward the pole, juſt

juſt as near the weſtern 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.

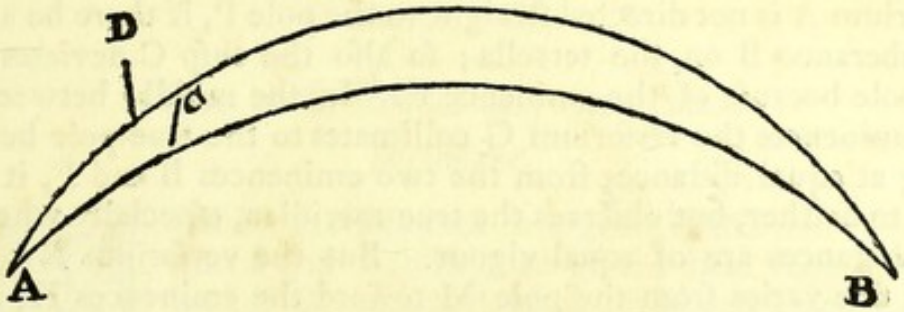


Let A be the pole, B the place of the variation, C the ſtronger regions; then the horizontal verſorium at B varies from the pole A toward C: ſo that both the variation is ſhown and the ſtronger places of the loadſtone recognized. The ſtronger ſurface is alſo found by a fine iron wire of the length of 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.



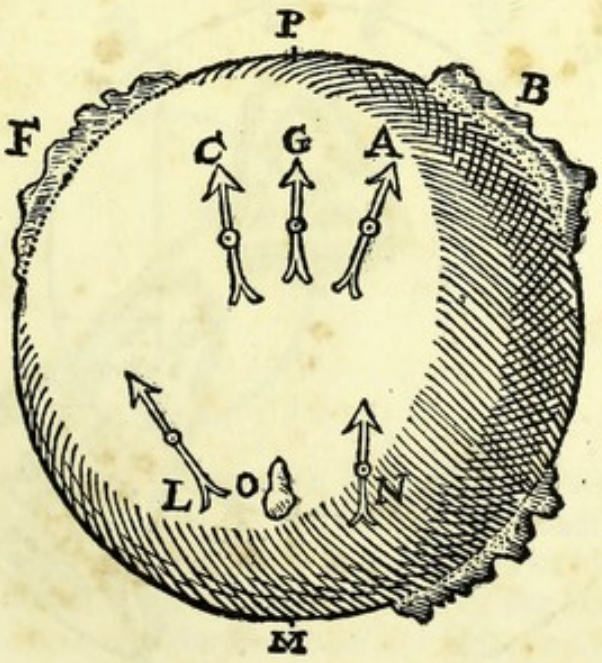
Let

Let the experiment be 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 all round and even it reſts on the pole directed toward any point of the æquator you pleaſe. Otherwiſe, let there be two *



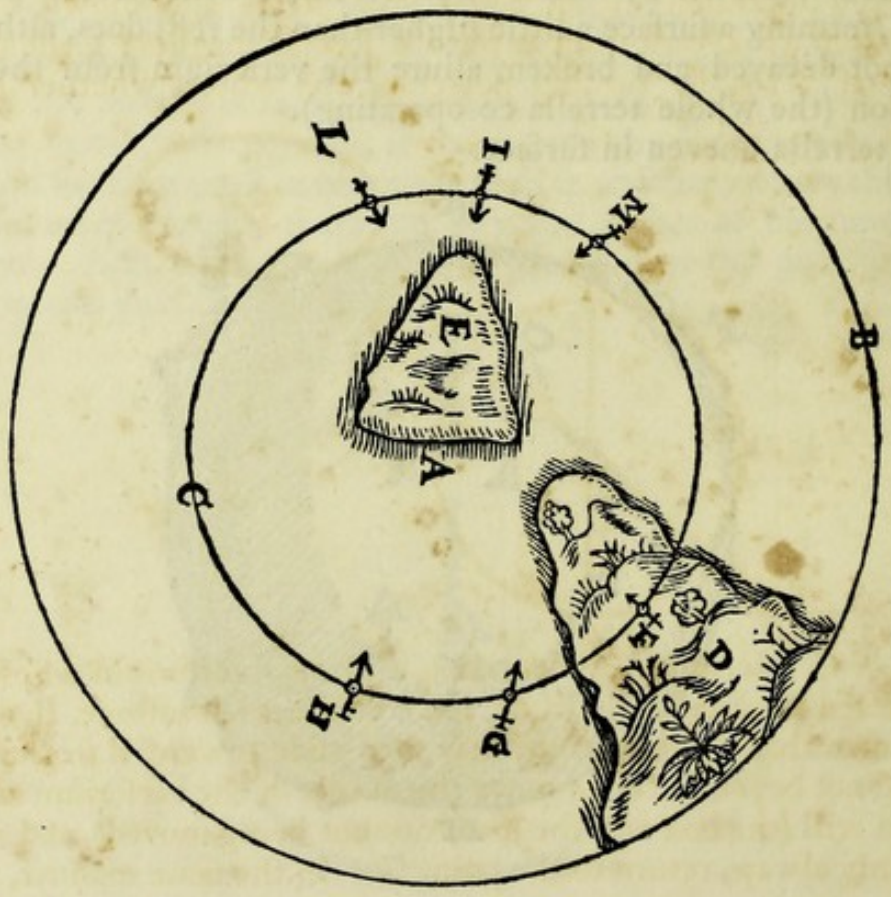
meridians meeting in the poles A B, let iron wires be reared juſt at the ends D and C of the equal arcs D A and C A; then the wire at D (the ſtronger region) will be more raiſed up than that at C, the weaker. And thus the ſounder and ſtronger part of the loadſtone is recognized, which otherwiſe would 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. 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

It is ſhown by a ſmall ſpike placed over a terrella or by a ſmall verſorium; for they are turned by 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 æquator, 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



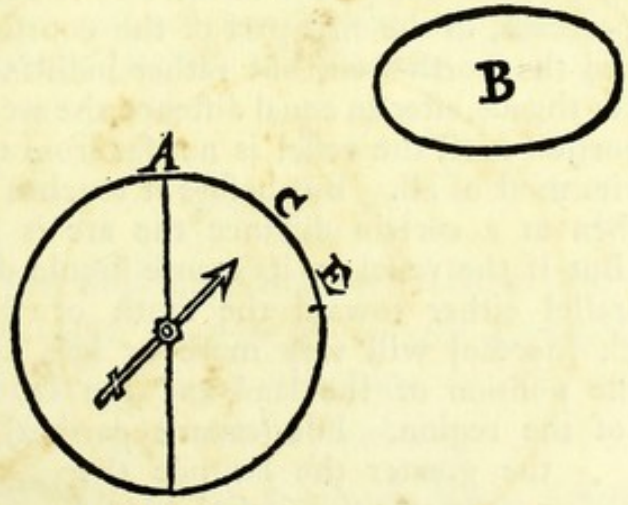
does

does not vary; while G 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

placed the ſtone ſo that 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.*

N 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, 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.

CHAP. V.

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

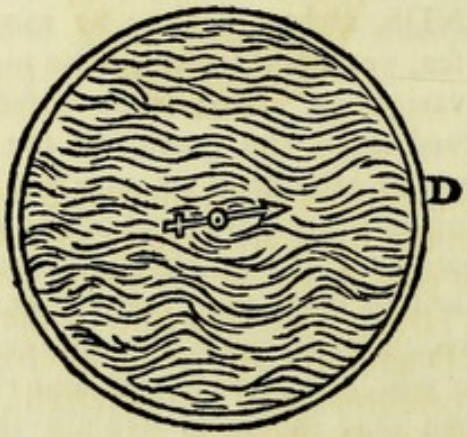
SLANDS, although they be more magnetick than the ſea, yet do not change the magnetick directions or variations. For ſince direction is a motion derived from the power of the whole earth, not from the attraction of any hill but from the diſpoſing and turning power of the whole; ſo variation (which is a perturbation of the direction) is an aberration of the real turning power ariſing from the great inæqualities 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.

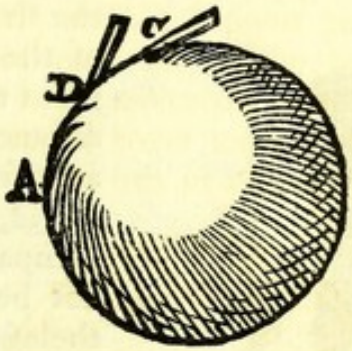
That variation and direction ariſe from the diſponent *power of the earth, and from the natural magnetick tendency* to rotation, not from attraction, or from coition, *or from other occult cauſe.*

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, Ro-

bert Norman, firſt ſtrove to ſhow that it is not cauſed by attraction: wherefore, as if tending toward hidden principles, he imagined a *point reſpective*, 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

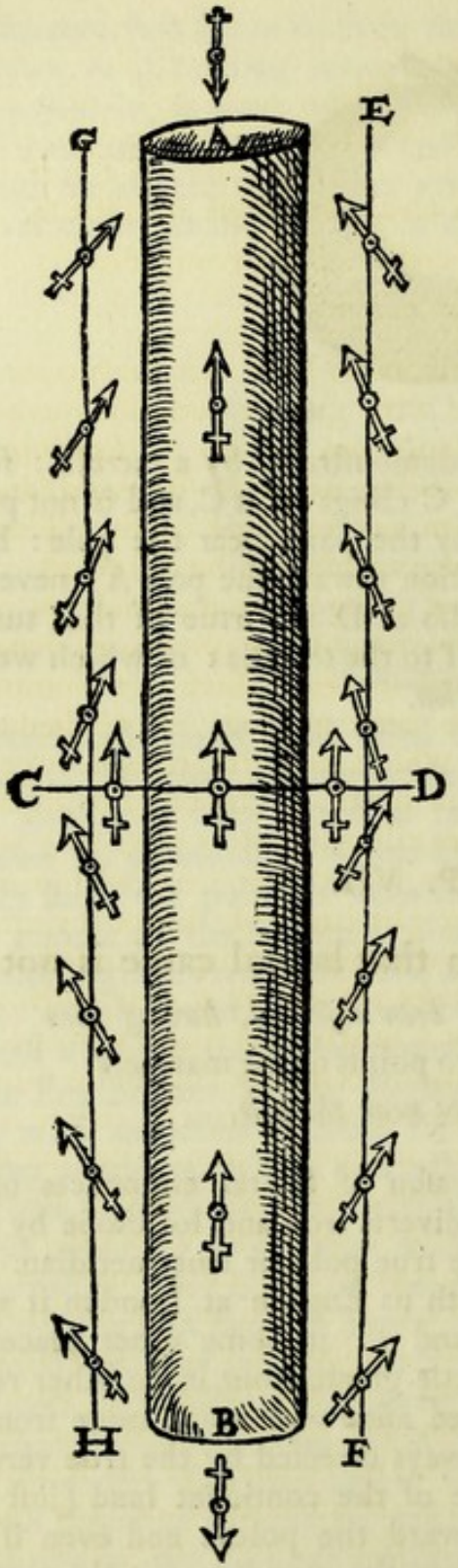


with the magnetick nature, as is demonſtrated by a terrella: for an iron ſpike placed on the ſtone at C clings on at C, and is not pulled further away by the pole A, or by the parts near the pole: hence it perſiſts at D, and takes a direction toward the pole A; nevertheleſs it clings on at D and dips 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



from diverſe cauſes. For 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.

CHAP. VIII.

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

IN a round 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

in which the iron works fixed below the circle diverge from the lily ¼ of a rumbe to the eaſt. For navigation to Ruſſia the divergency is ⅜. 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.*

GRATEFUL 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

"point of the needle will decline the more to the weſt" (which is totally untrue), he thinks 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

iſland, yet in 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: 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;

verſorium; 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*.

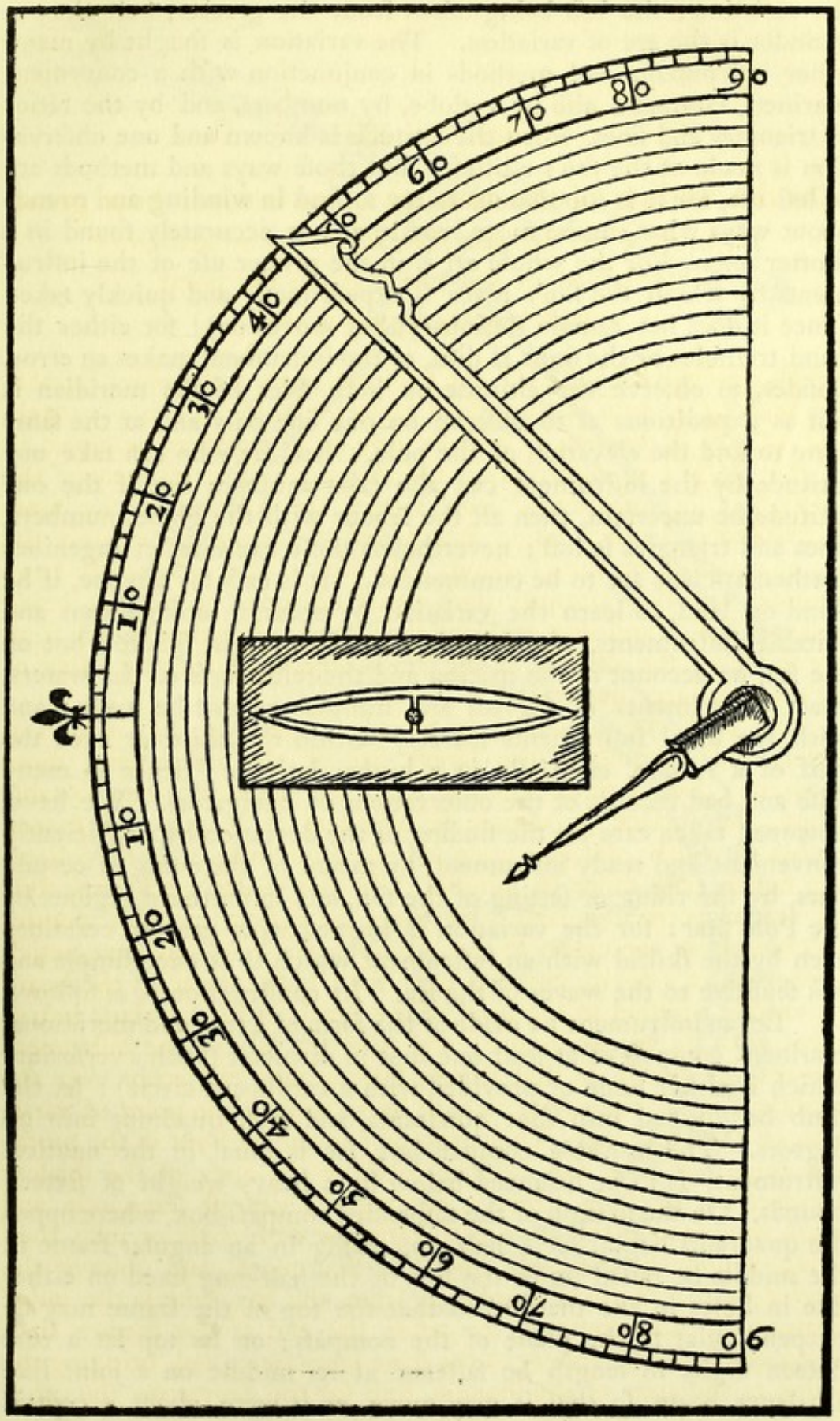
ONE may very eaſily fall into miſtakes and errors when one is ſearching into the hidden cauſes of things, in the abſence of real experiments, and this is eaſily apparent from the craſs error of Cardan; who deems himſelf to have diſcovered the diſtances of the centres of the coſmos and of the earth through 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.

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 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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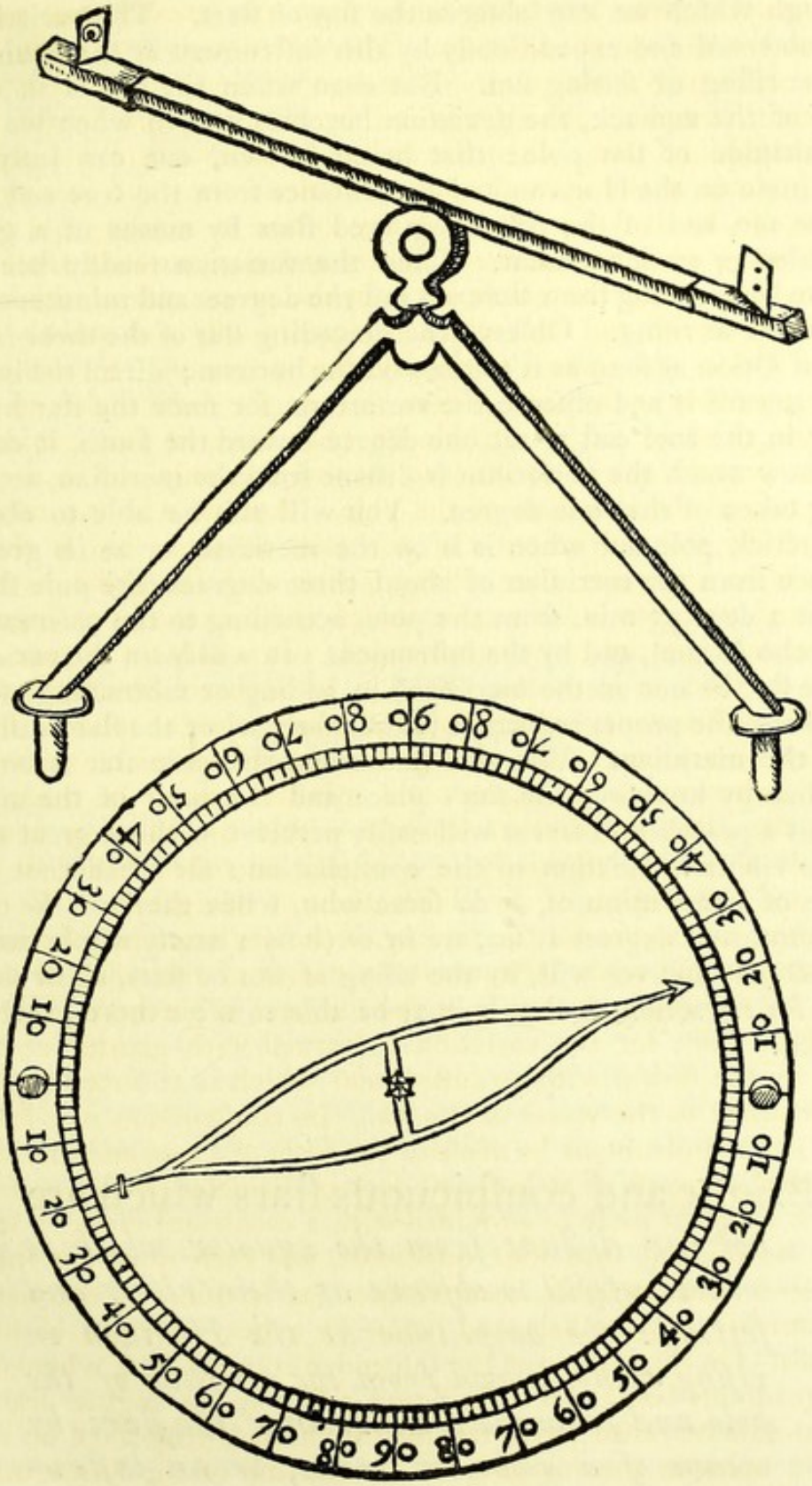
the variation; the leſs being taken from the greater, half the remainder is the arc of variation. The variation is ſought by many other inſtruments and methods in conjunction with a convenient mariners' compaſs; alſo by a globe, by numbers, and by the ratios of triangles and ſines, when the latitude 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 half 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.

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



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*] 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 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.

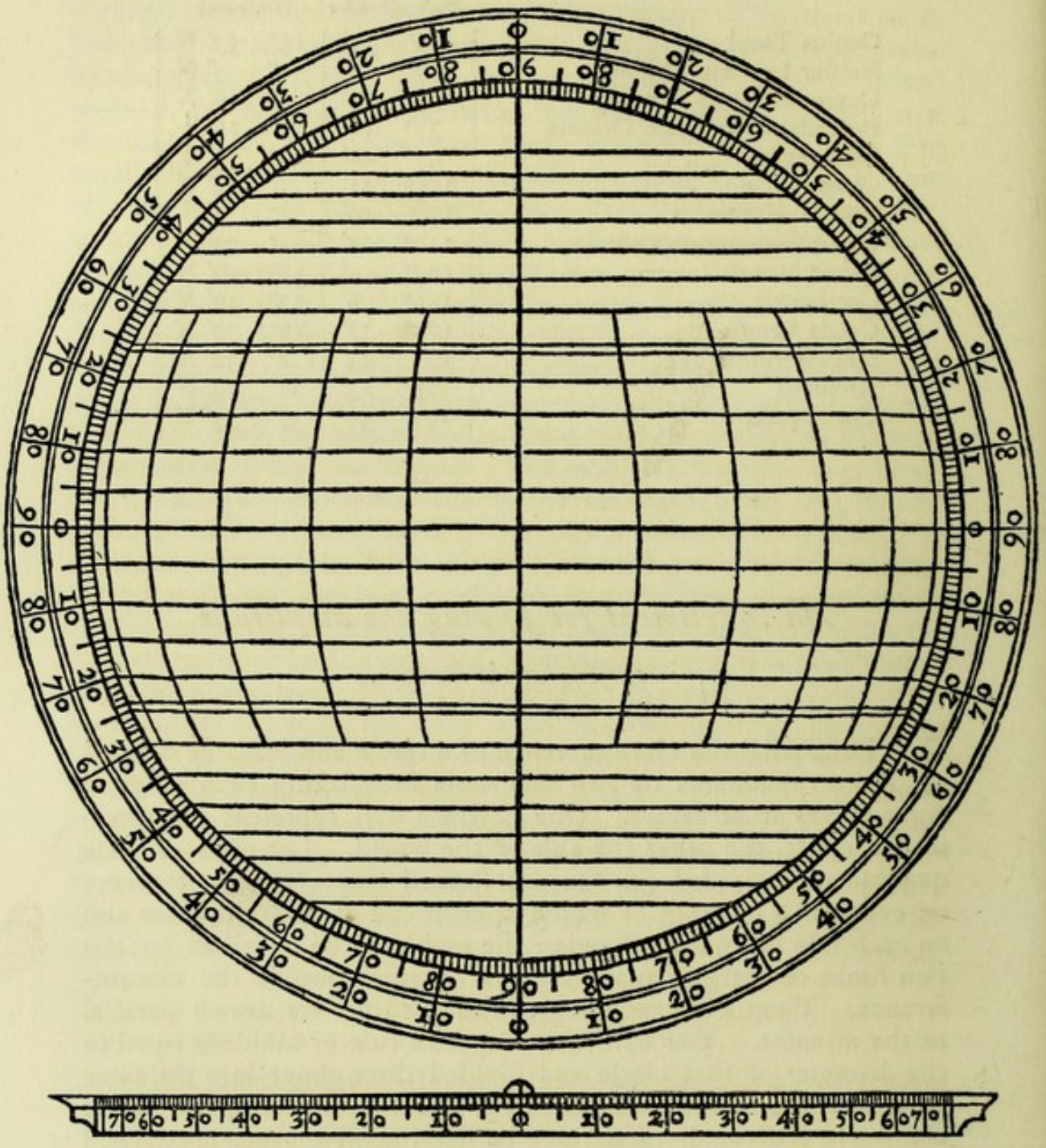
Bright and conſpicuous ſtars which are *not far diſtant from the æquator which it will be uſeful to obſerve at their riſing and ſetting: the amplitude at the Horizon on riſing being known from the altitude of the pole and from the declination of the ſtars, by means of a globe, or tables, or an inſtrument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

	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.

Therefore



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.

CHAP. XIII.

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 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 Agulhas 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

Cape St. Auguſtine and thence to Cape Frio, and further ſtill 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

that the truth becomes known in ſuch a high 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.

PASSING 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.

SICILIAN 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

toward the 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.*

MOST 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.

VARIATION 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

bique the verſorium inclines ¼ rumbe or even more to the ſouth-weſt. Very wrongly alſo 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.

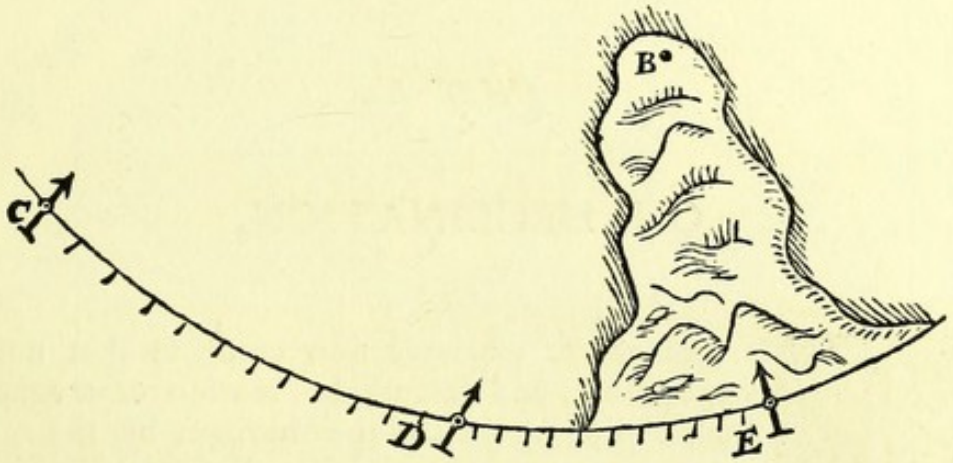
How the deviation of the verſorium is augmented and *diminiſhed by reaſon of the diſtance of places.*

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

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.

A



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.

BOOK FIFTH.

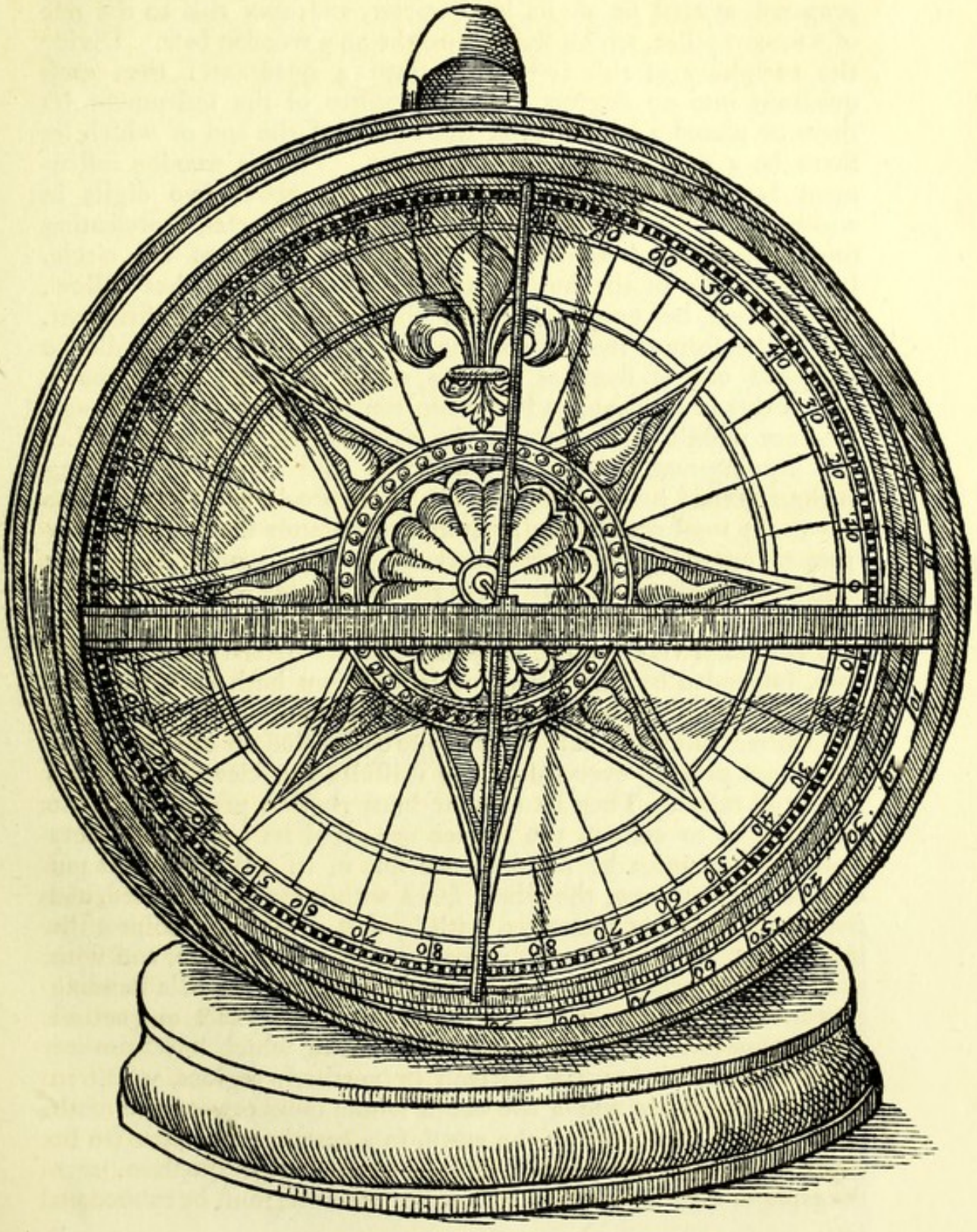
CHAP I.

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.

Inſtrument

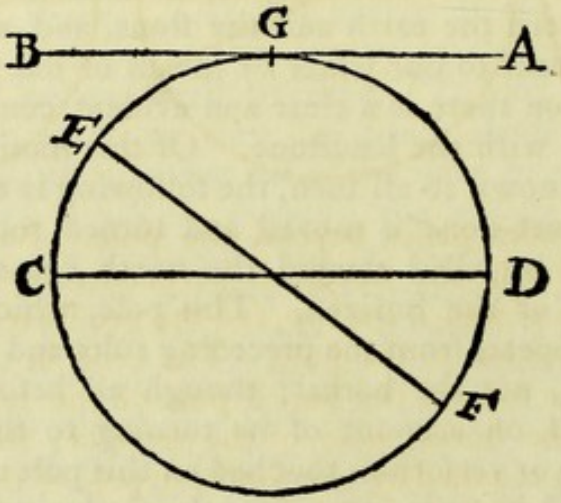
Inſtrument of the Declination.



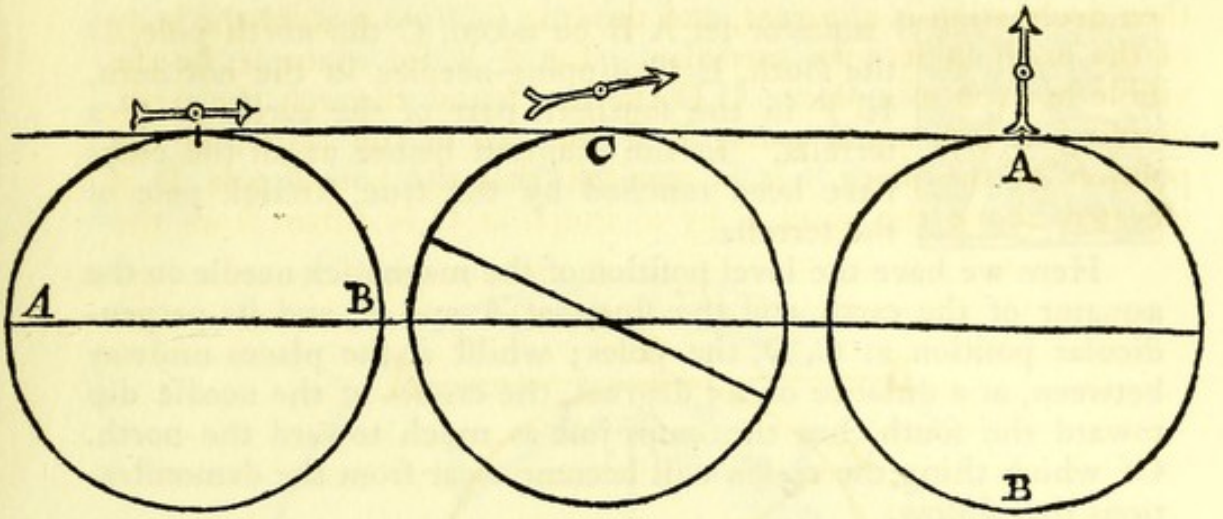
Now how much it dips at every horizon may be aſcertained in the firſt place by a contrivance, which, however, is not ſo eaſily made as is that in dials for meaſuring time, in which the needle turns to the points of the horizon, or in the mariners' compaſs. From a plank of wood let a ſmooth and circular 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 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 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. 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

then declination is apparent, and the iron 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



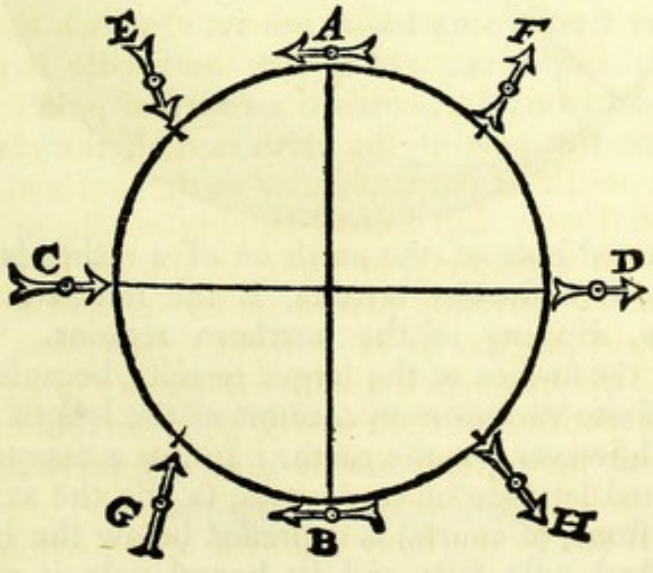
æquator. Wherefore, ſince at E the magnetick needle ſtands perpendicularly in its proper turning (as we have often ſhown before), ſo now at G there is a certain tendency to turn in proportion to the latitude (the magnetick dipping below the plane of the horizon), and the magnetick body interſects the 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 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 æquilibrium. 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



dip in higher latitudes paſſes beyond the pole. But in the third poſition of the 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 poſitions of the ſphere, and horizons* of the earth, in which there is no varia- *tion of the declination.*

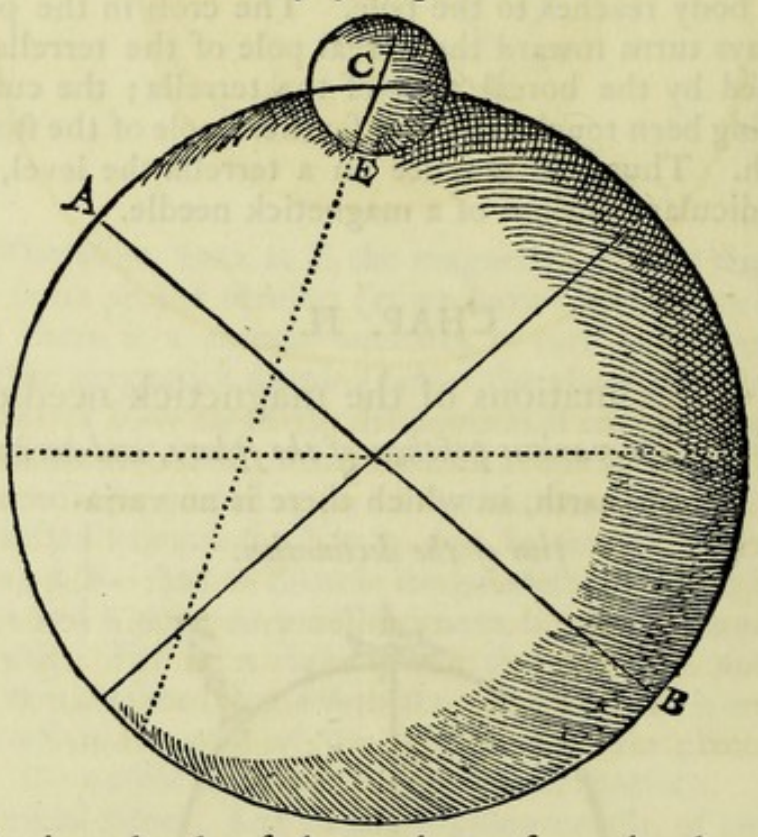


As

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.

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.

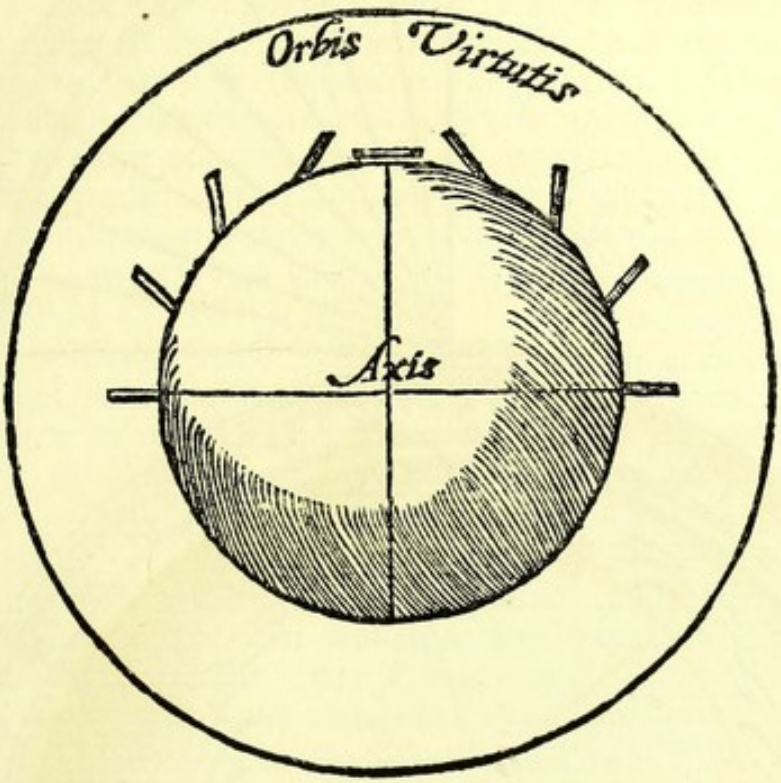
✶ *Diagram of the rotation and declination of a terrella* conforming to the globe of the earth, for a *latitude of* 50 *degrees north.*



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. 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

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.

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

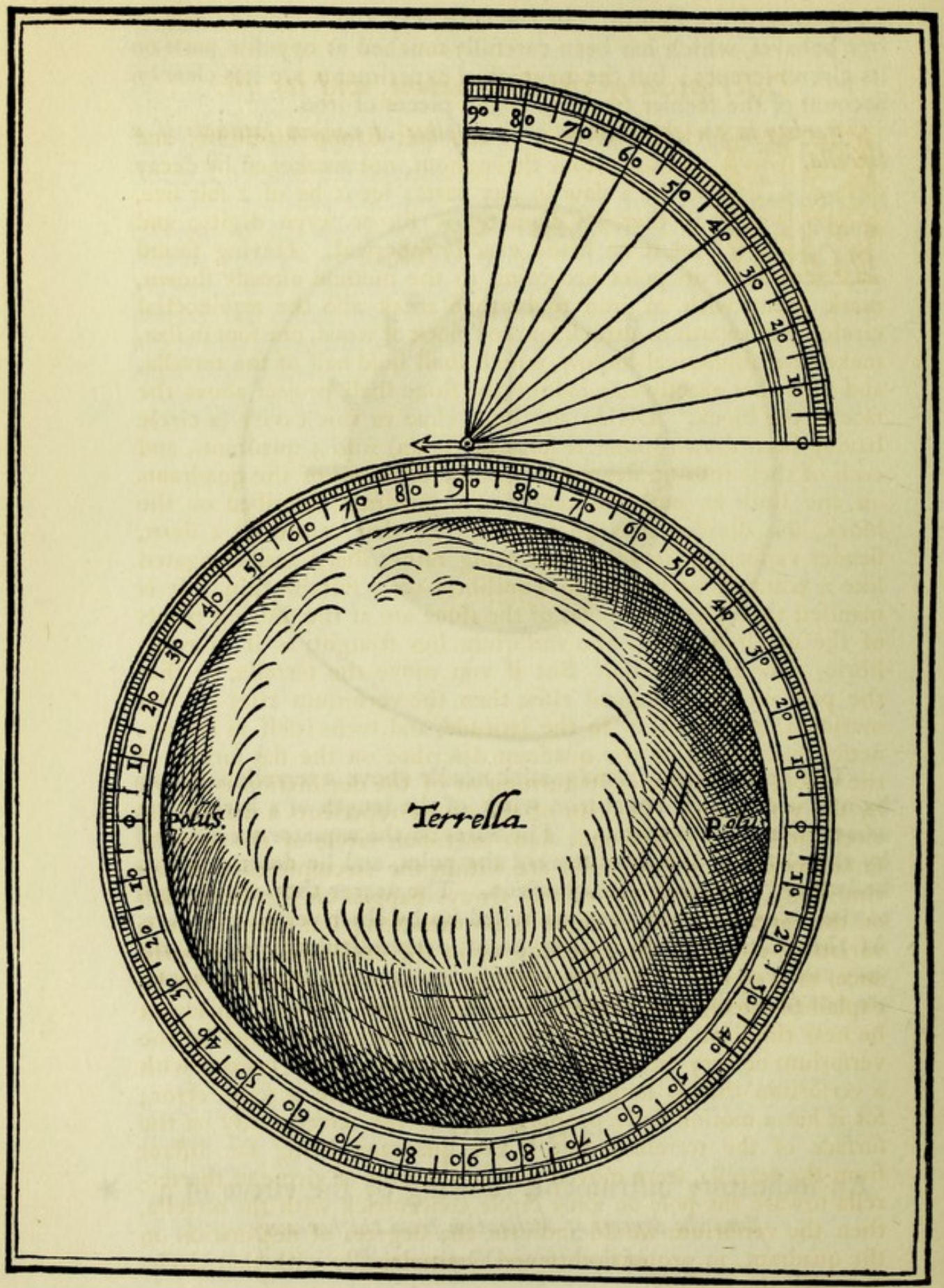


The declination of a magnetick needle above a terrella is ſhown by means of ſeveral equal iron wires, of the length of a barleycorn, arranged along a meridian. The wires on the æquator are directed by the virtue of the ſtone toward the poles, and lie down upon its body along the plane of its horizon. 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.

Deſcription


Terrella
Polus.

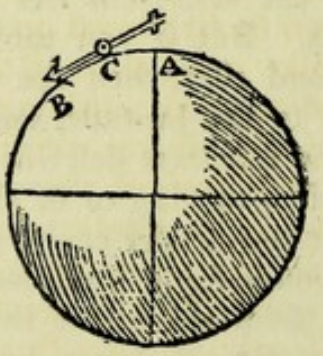
Deſcription of the Inſtrument, and its uſe.

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.

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 æquator 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.

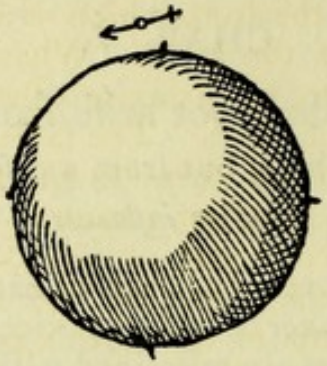
CHAP.

CHAP. V.

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

N 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. 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



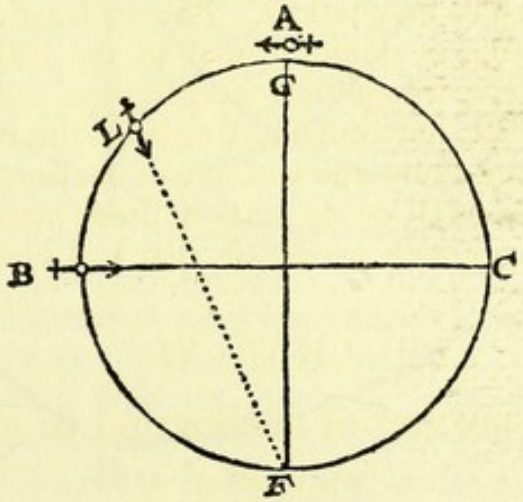
For the cuſp of a verſorium placed in a low latitude does not touch the ſtone or unite with it, but only inclines toward it. Moreover, when a magnetick body rotates in dipping, the pole of the verſorium is not ſtayed or detained by the pole of the earth or terrella; but it rotates regularly, and does 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; 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, and *the cauſe of it.*

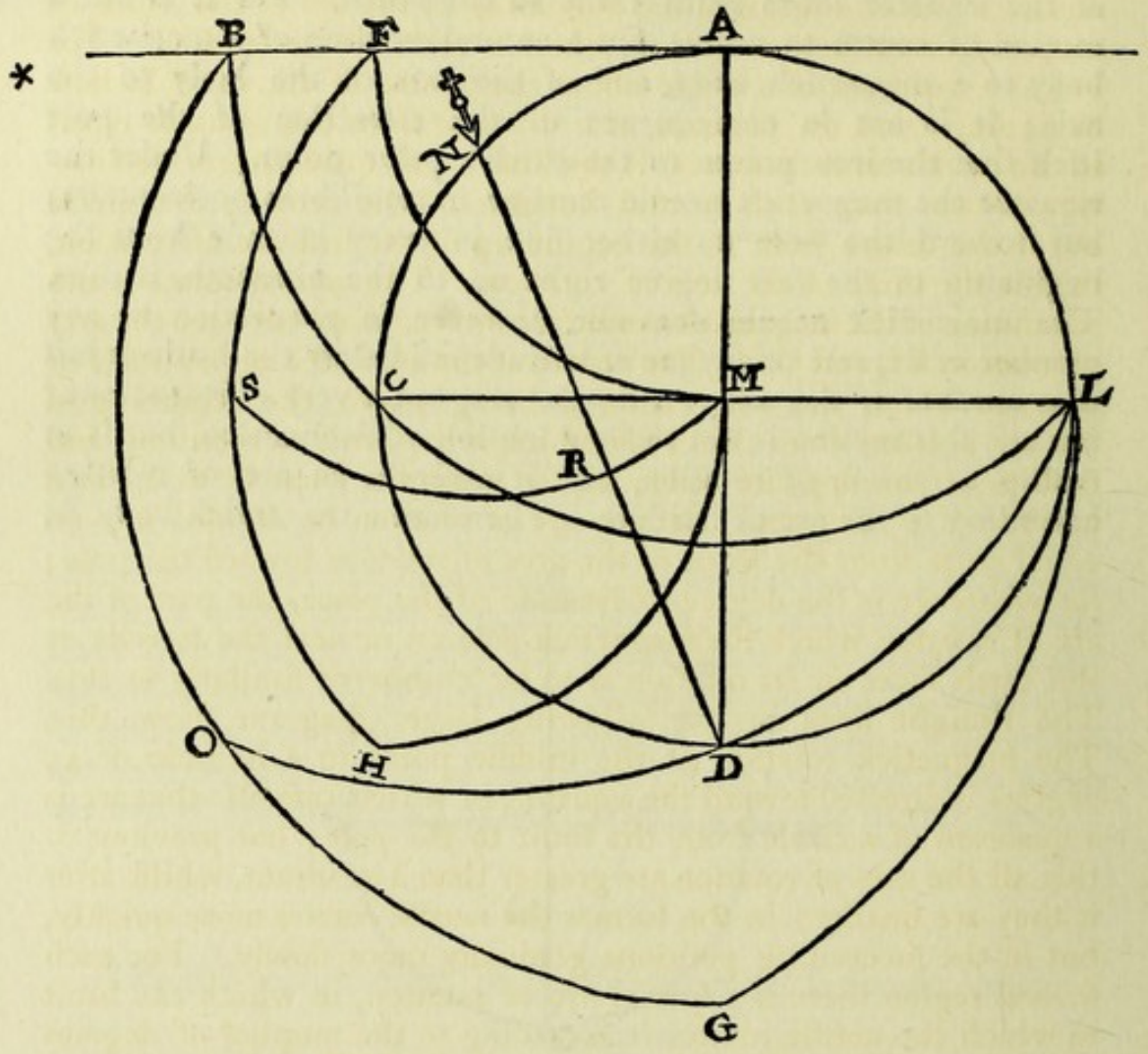
CONCERNING the making of an inſtrument for finding declination, the cauſes and manner of declination, and the different degrees of rotation in different places, the inclination of the ſtone, and concerning an inſtrument indicating by the influence of a ſtone the degree of declination from any horizon 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 æquator 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

the ſtone) the axis of the iron, which is its centre line, is a line parallel to the axis of the earth. 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 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

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.



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

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.

CHAP.

CHAP. VIII.

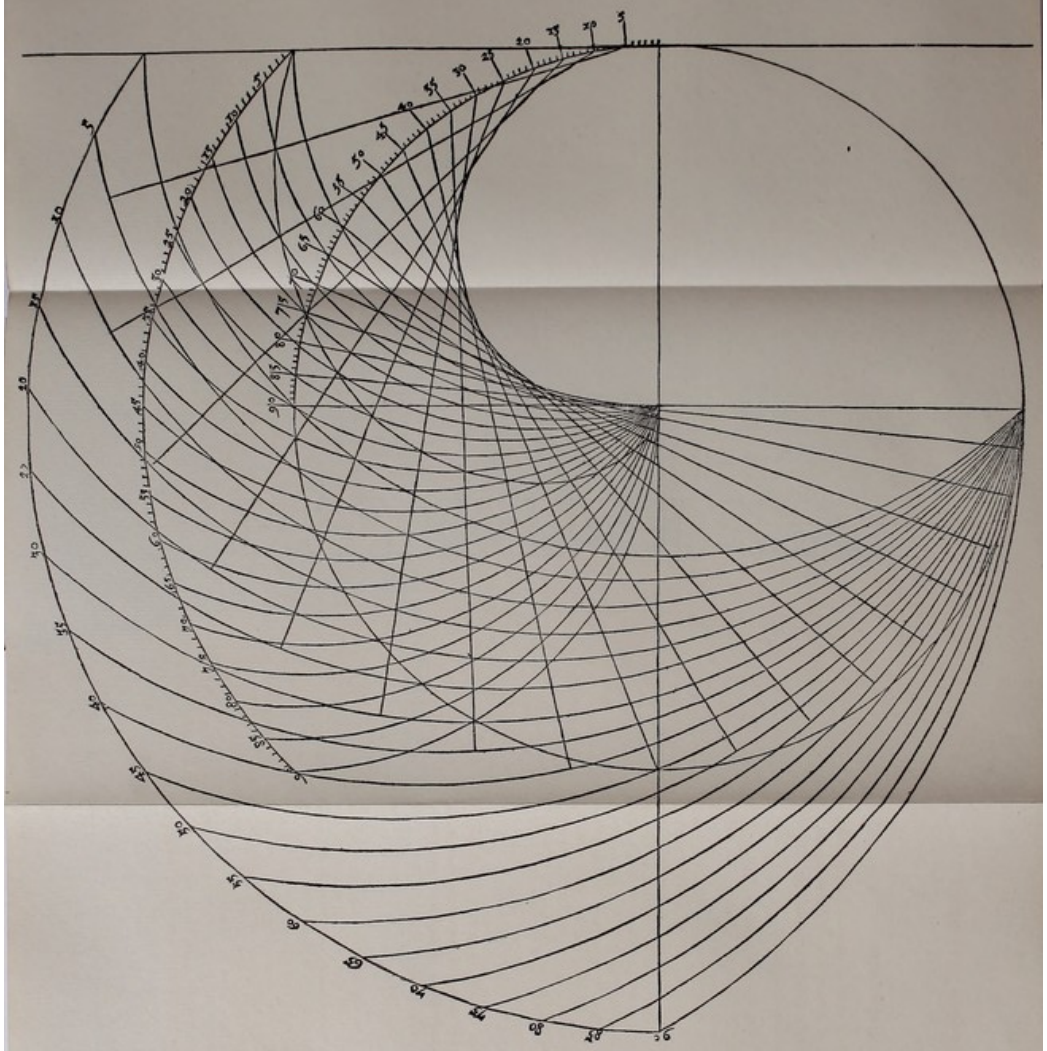
Diagram of the rotation of a magnetick needle, indicating magnetical declination in all latitudes, and from the rotation and declination, the latitude itſelf.

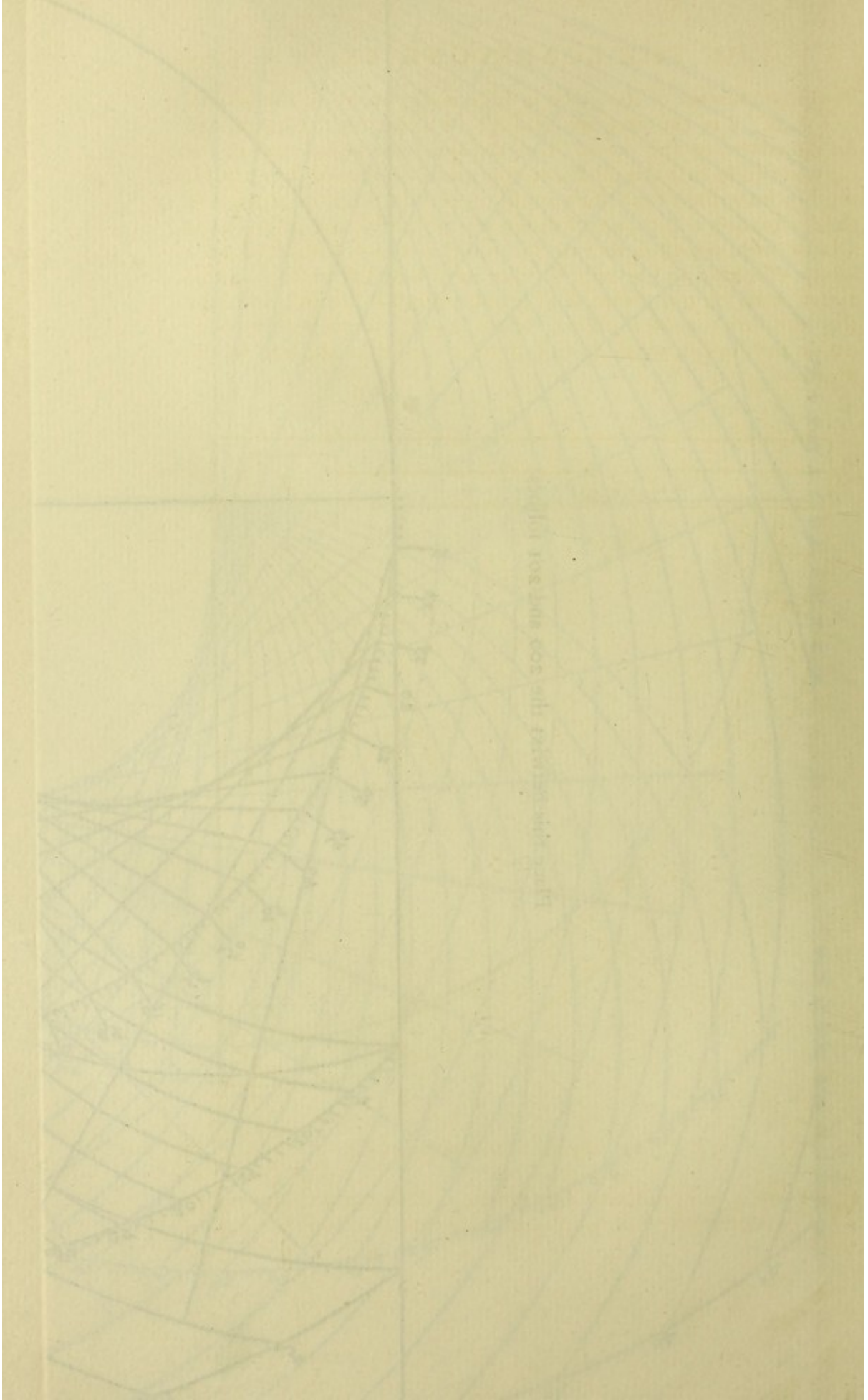
IN the more elaborate diagram a circle of rotations and a circle of declinations are adjuſted to the body of the earth or terrella, with a firſt, a laſt, and a middle arc of rotation and declination. Now from each fifth diviſion of the arc which limits all the arcs of rotation (and which are underſtood 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.

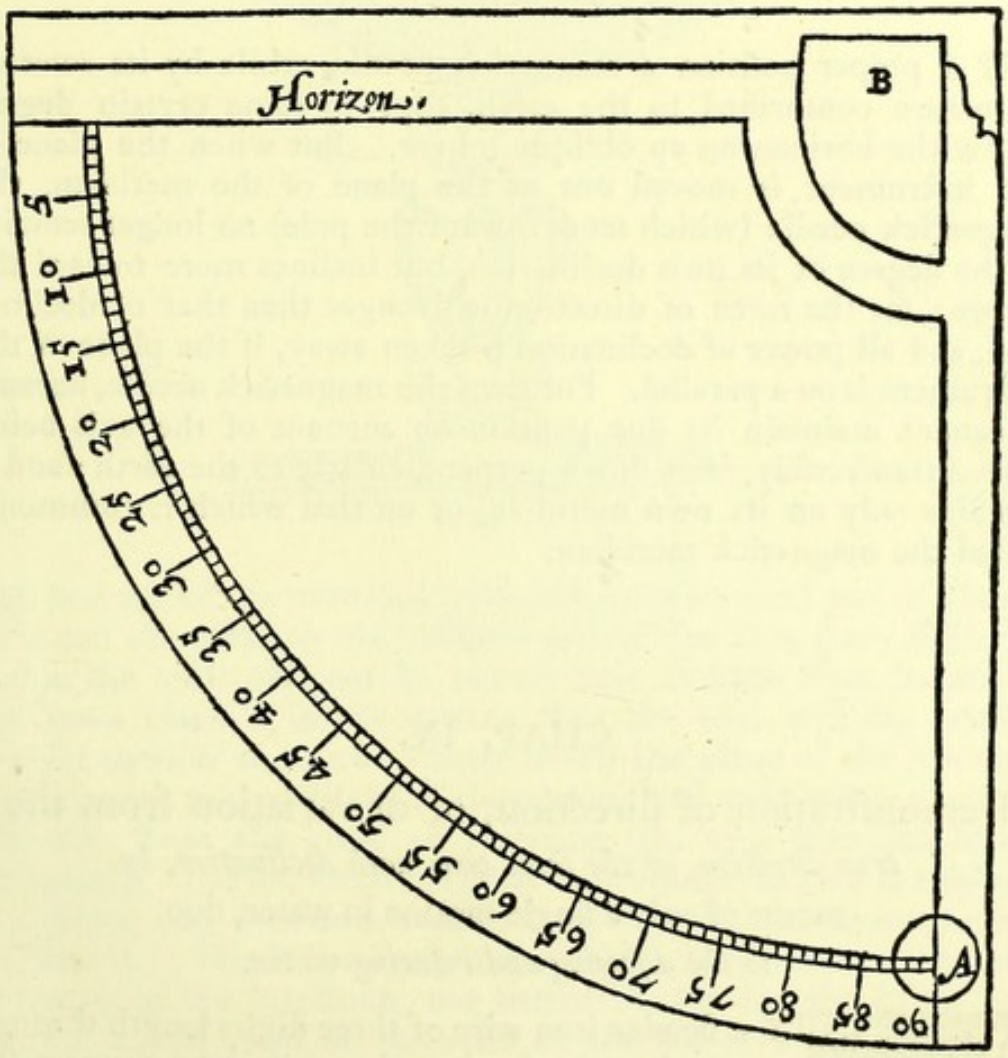
WE may ſee how far from unproductive magnetick philoſophy is, how agreeable, how helpful, how divine! Sailors when toſſed about on the waves with continuous cloudy weather, and unable by means of the cœleſtial luminaries to learn anything about the place or the region in which they are, with a very ſlight 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

Place this betwixt the 200 and 201 folioes





the circumference of the globe is diſcerned by means of the fiducial line 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.

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

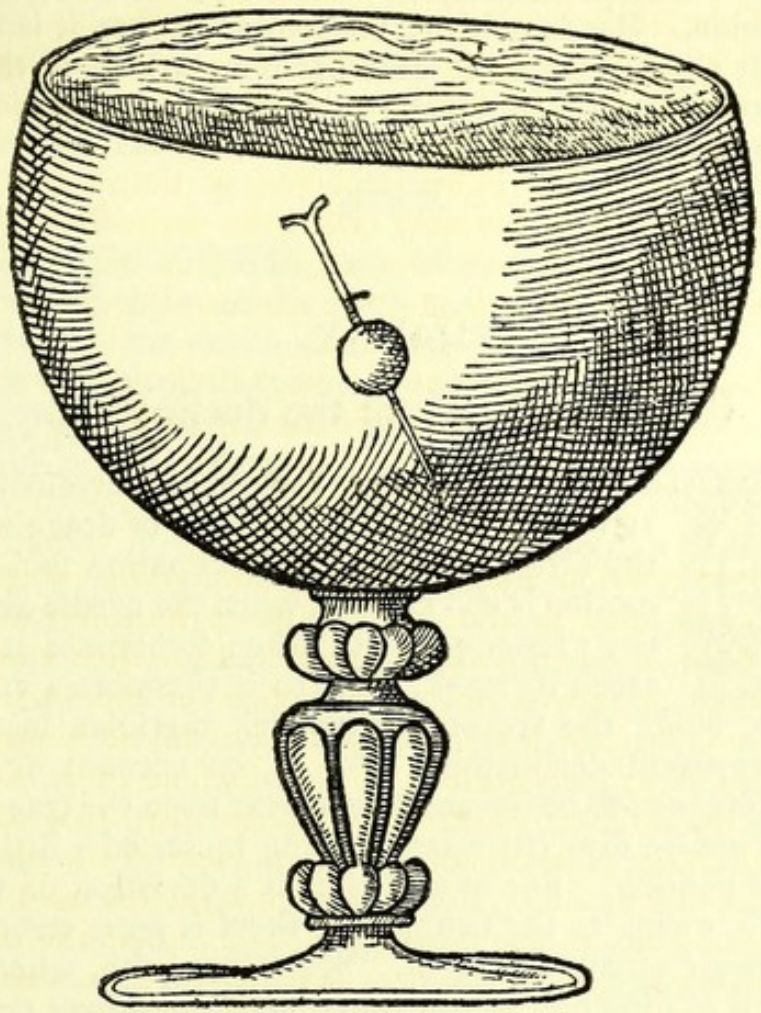
IN a proper poſition a magnetick needle, while by its rotatory nature conformed to the earth, dips to ſome certain degree below the horizon on an oblique ſphere. But when the plane of the inſtrument is moved out of the plane of the meridian, the magnetick needle (which tends toward the pole) no longer 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 ſurface of the water; and let the wire be evenly balanced.

Rub



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,

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.

CHAP. X.

On the variation of the declination.

*  IRECTION 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.

CHAP. XI.

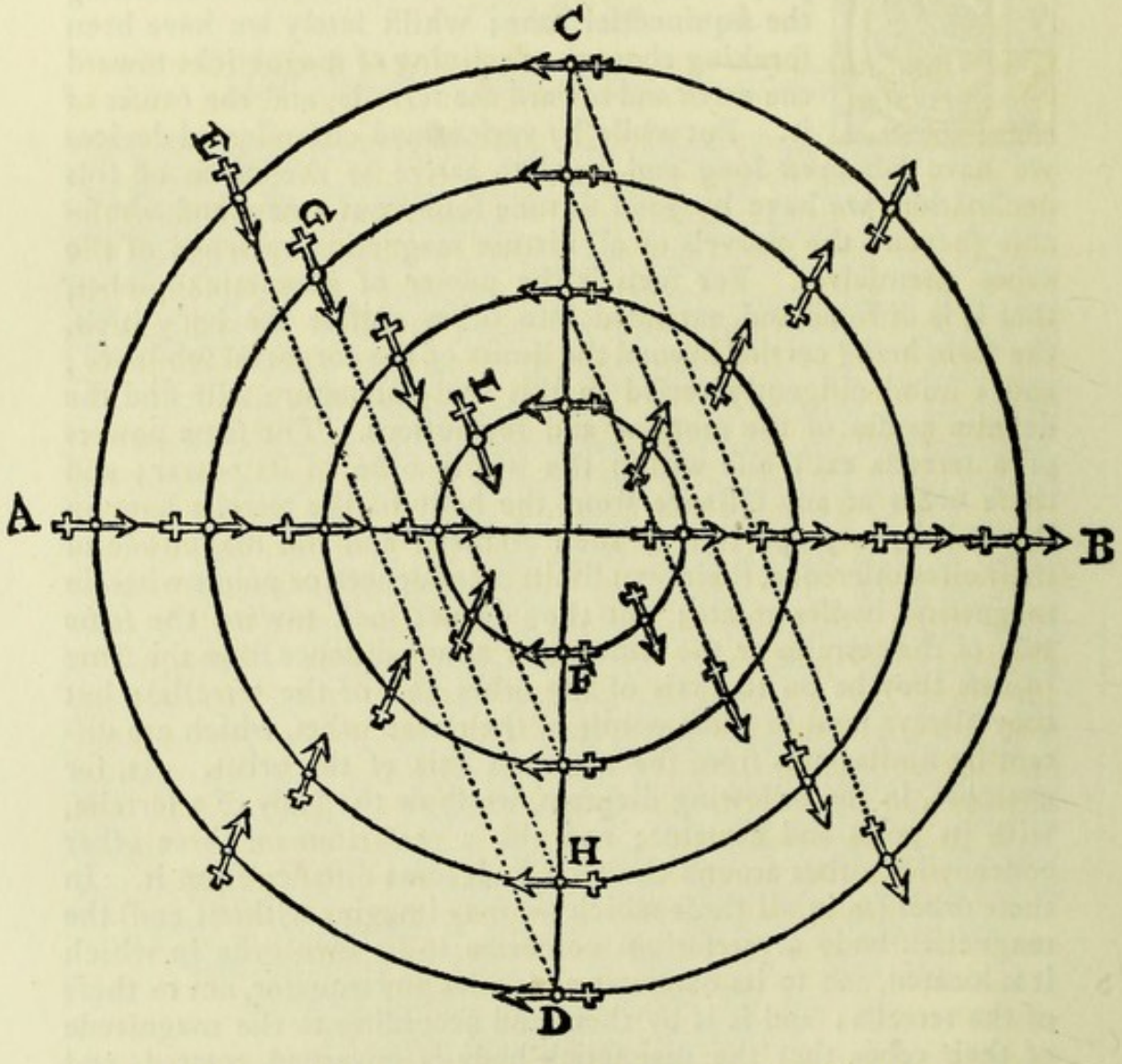
On the eſſential magnetick activity ſphærically *effuſed.*

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

diſpoſe magneticks and incite them, as if the orbes of 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 æquator 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 terrella, ſo is that of G to H on its orbe and of E to D on its orbe; alſo all the rotations on the

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.

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.

CHAP.

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

With it alſo they 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 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.

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

been annulled by fire, it acquires new verticity, 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 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. Wherefore the opinion of Dominicus Maria of Ferrara, a moſt talented man, who was the teacher of Nicolas Copernicus, muſt be cancelled; a view which,

which, according to certain obſervations of his own, is as follows. "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 obſerva- "tion has already begun to diſcloſe to us things hidden from our fore- "fathers; 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 eleva- "tions 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 ſun- "ſet 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 diver- "gence 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 move- "ment 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 $\frac{2}{3}$: 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

the centre of the world, 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 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 (among later diſcoverers, a man moſt deſerving of literary honour) is the firſt who attempted to illuſtrate the φαινόμενα of moving

moving 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 the ſuppoſed and imaginary orbes 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, 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

would be! It is evident then that all the heavenly bodies ſet as if in deſtined places are there 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 all to take place eaſtward and following the order of the ſigns. The

The common run of 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 wiſe 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 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 philo-

ſophers

ſophers, as of theologians, muſt be gentle, happy, and tranquil, and not at all 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

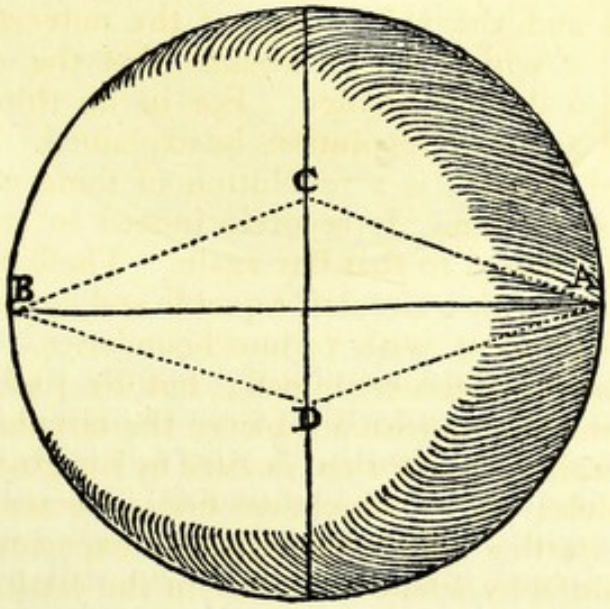
ſince nature always acts through a few rather than through many; and it is more agreeable to reaſon that the Earth's one ſmall body ſhould make a diurnal rotation, than that the whole univerſe ſhould be whirled around. I paſs over the reaſons of the Earth's remaining motions, for at preſent the only 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). 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.

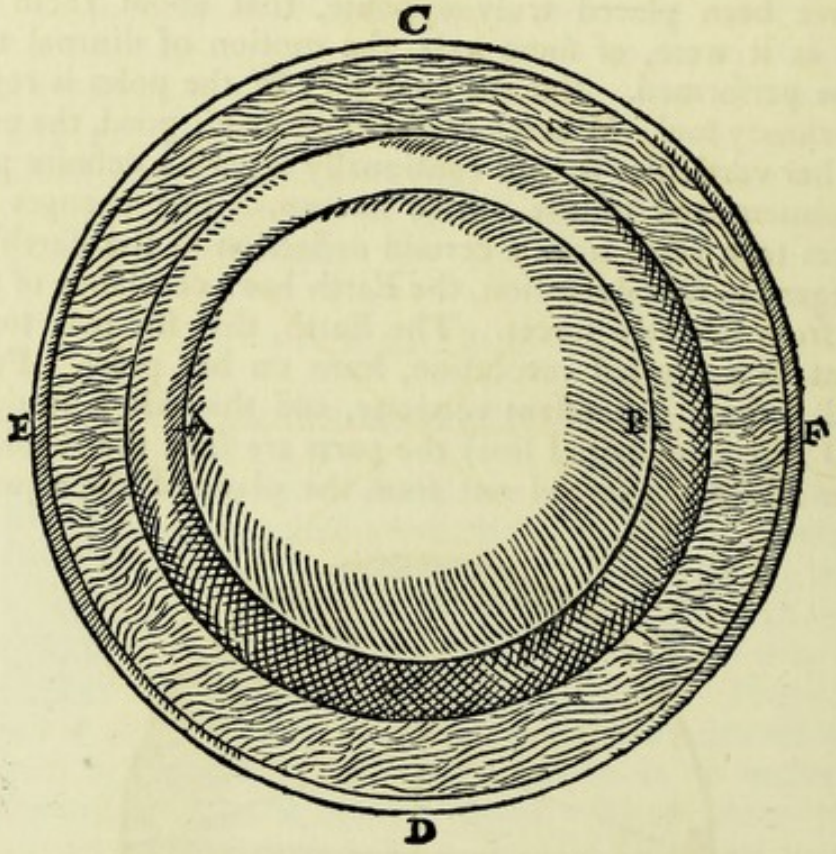
F then the philoſophers of the common ſort, with an unſpeakable abſurdity, imagine the whole heaven and the vaſt extent of the univerſe to rotate in a whirl, it yet remains that the earth performs a diurnal change. For in no third way can the apparent revolutions be explained. This day, then, which is 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;*

Mobile; but thoſe are the conception of an unſettled imagination. Wherefore we, 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, 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 to-



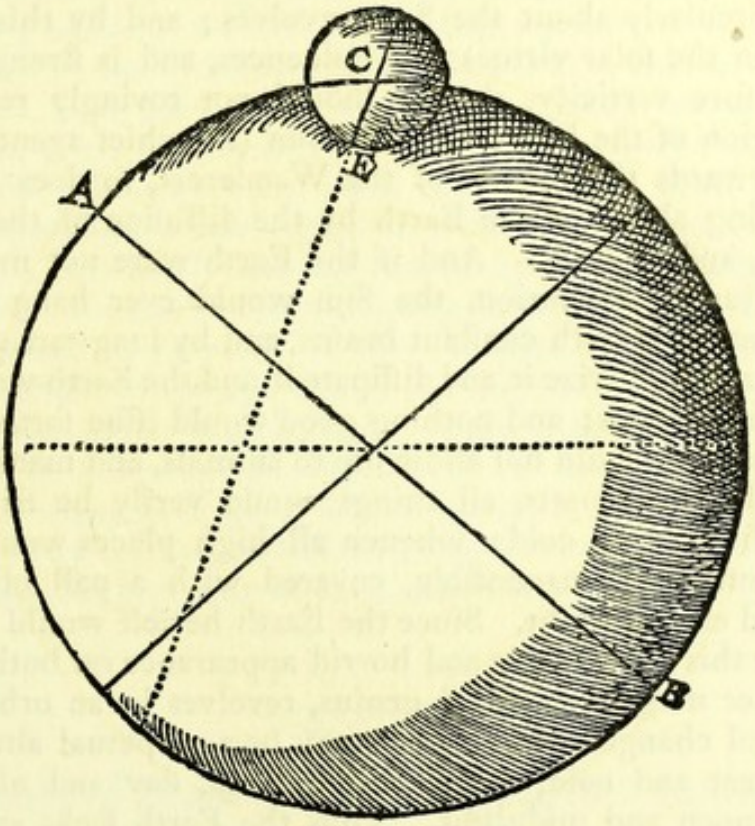
ward the poles, in æther which is free from renitency, or elſe in a void; and A and B remaining conſtant, C revolves toward D both from innate conformity and aptitude, and for neceſſary good, and the avoidance of evil; but being chiefly moved forward by the diffuſion of the ſolar orbes of virtues, and by their lights. And 'tis borne around, not upon a new and ſtrange courſe, but (with the tendency

tendency common to the 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

places is no other than circular. The whole Earth regards the Cynoſure with her 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 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 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

in every part. The Earth is moved by 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

rejoices, and is refreſhed: nor could ſhe endure them for ever on one particular ſide 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 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 retro- " greſſions 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 ſwift 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

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are at reſt in the air, unleſs the force of the winds drive them; and objects which are projected into the air fall again into their own place. But thoſe fooliſh ſolk 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 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 conſiſtent 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 ridicul-

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ous. For air is only exhalation, and is an enveloping effluvium from the Earth itſelf; the 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

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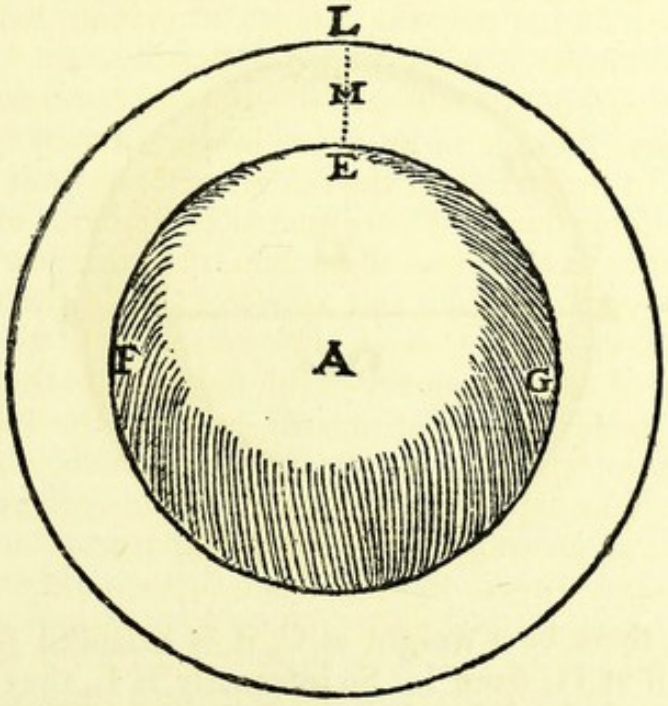
ſolid circumference from the ſurrounding bodies; but all her effluvia ſurround her, and in them heavy bodies projected in any way by force, move on uniformly along with the Earth in general cohærence. And this alſo takes place in all primary bodies, the Sun, the Moon, the Earth, the parts betaking themſelves 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.

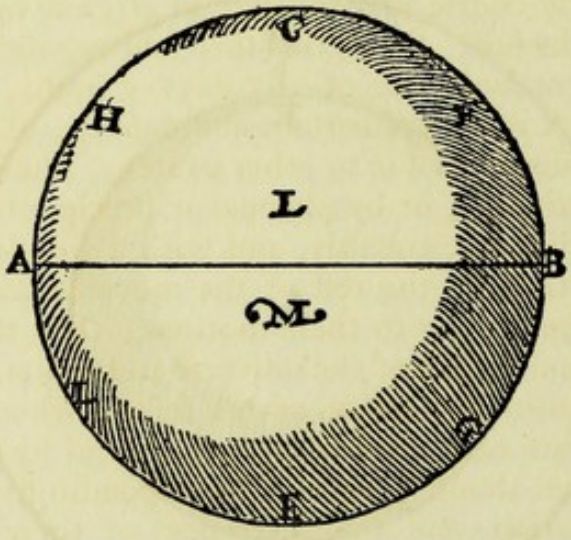


Let E F G be the Earth's globe, A its centre, L E the aſcending effluvia: Juſt as the orbe of the effluvia progreſſes with the Earth, ſo alſo does the unmoved part of the circle at the ſtraight line L E progreſs along with the general revolution. At L and E, a heavy body, M, falls perpendicularly toward 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

is by no means refuted by the illuſtrious Tycho Brahe, through arguments ſuch as theſe.

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 ſlighteſt 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.

CHAP.

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 $\frac{1}{4}$ 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 $\frac{5}{6}$ diameters of the Earth from the Earth's centre. The Moon's revolution with reſpect to the Sun takes place in 29$\frac{1}{2}$ days and 44 minutes of time. We reckon the motion with reſpect to the ſun, not the periodic motion,

juſt

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 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 Cælo*, 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 inhærent 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.

CHAP.

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 præceſſion of the æquinoxes is apparent to us.

CHAP.

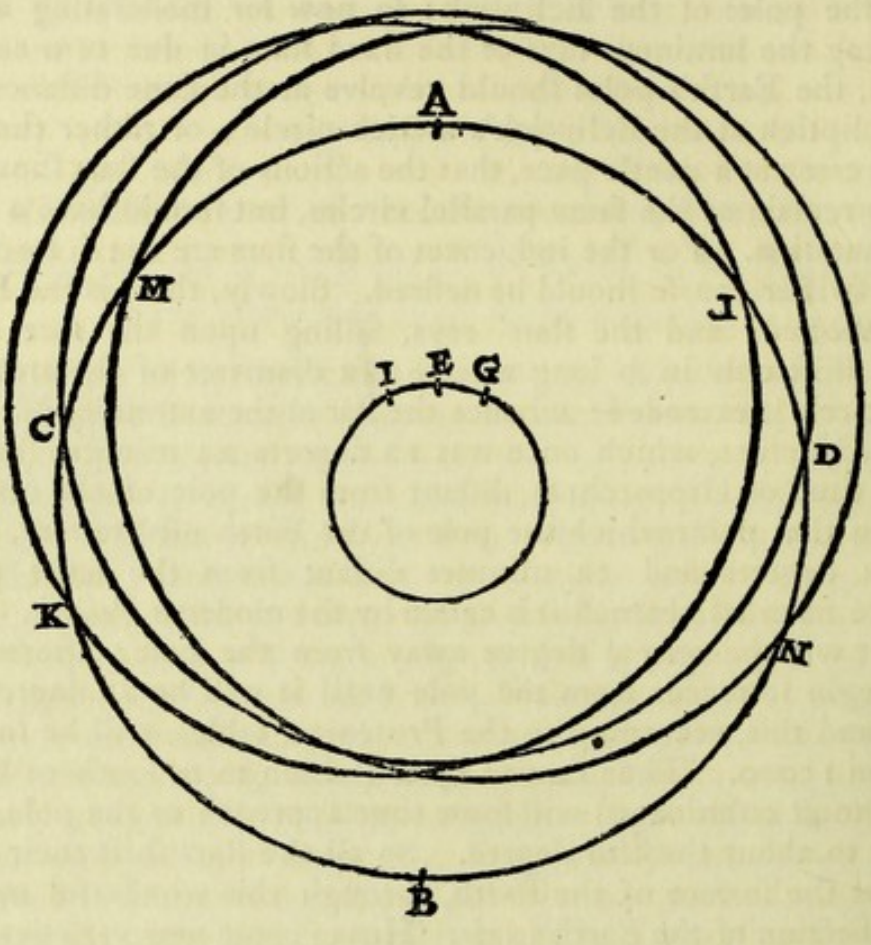
CHAP. VIII.

On the Præceſſion 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 inæqualities 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 demonſtrate 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 by this motion the riſings 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

from the poles of the Ecliptick: ſo now for 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 æquable 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.



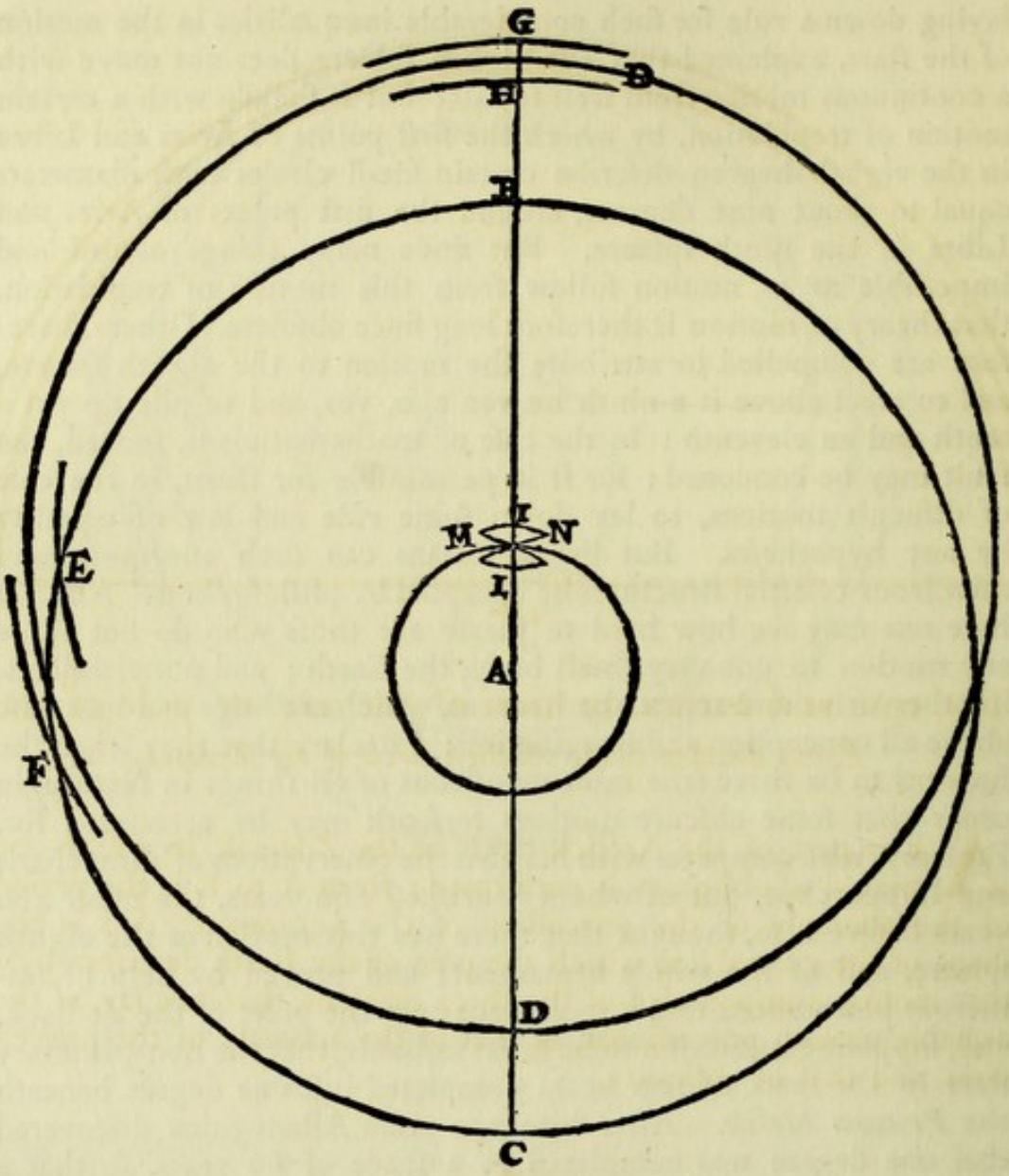
CHAP. IX.

On the anomaly of the Præceſſion of the Æquinoxes, *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 æquator 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 inæquality of the præceſſion and alſo of the obliquity of the tropicks. Thebit, with the view of laying,

laying down a rule for ſuch conſiderable inæqualities 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 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 phænomena 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 ſtriving after through ſuch inæquality 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

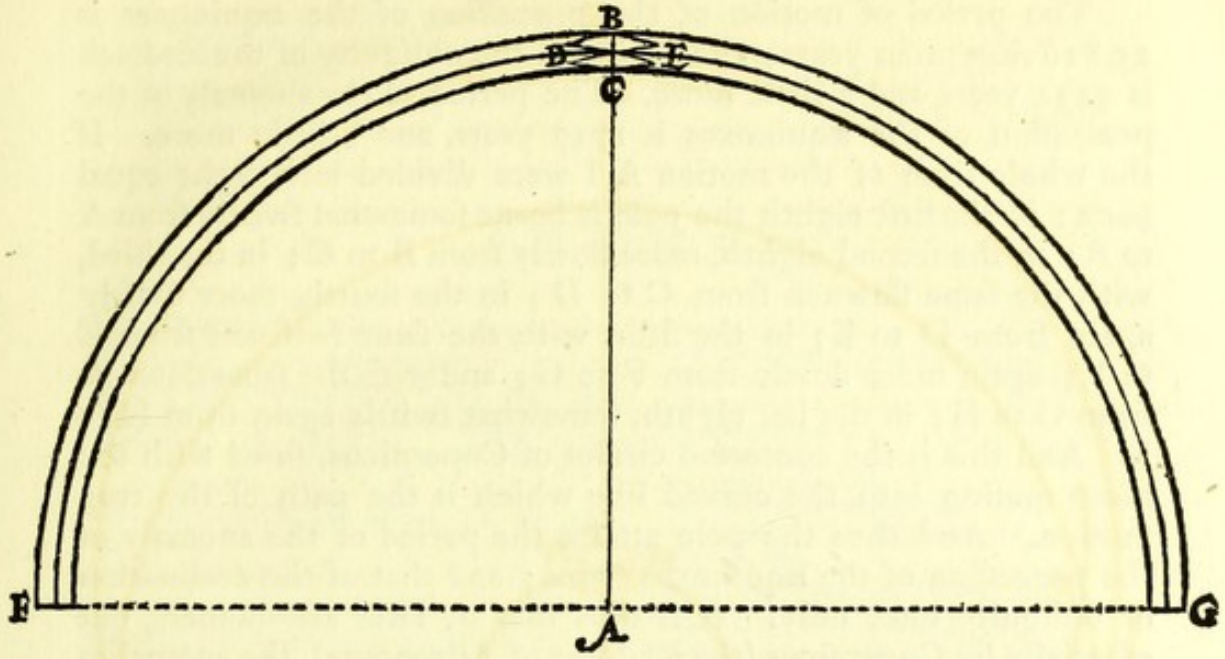


but when it faces N, there is an anomaly of the præceſſion at E. But when it faces I directly, then the maximum obliquity G is obſerved at the ſolſtitial colure; but when it faces L, there is the minimum obliquity H at the ſolſtitial colure.

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

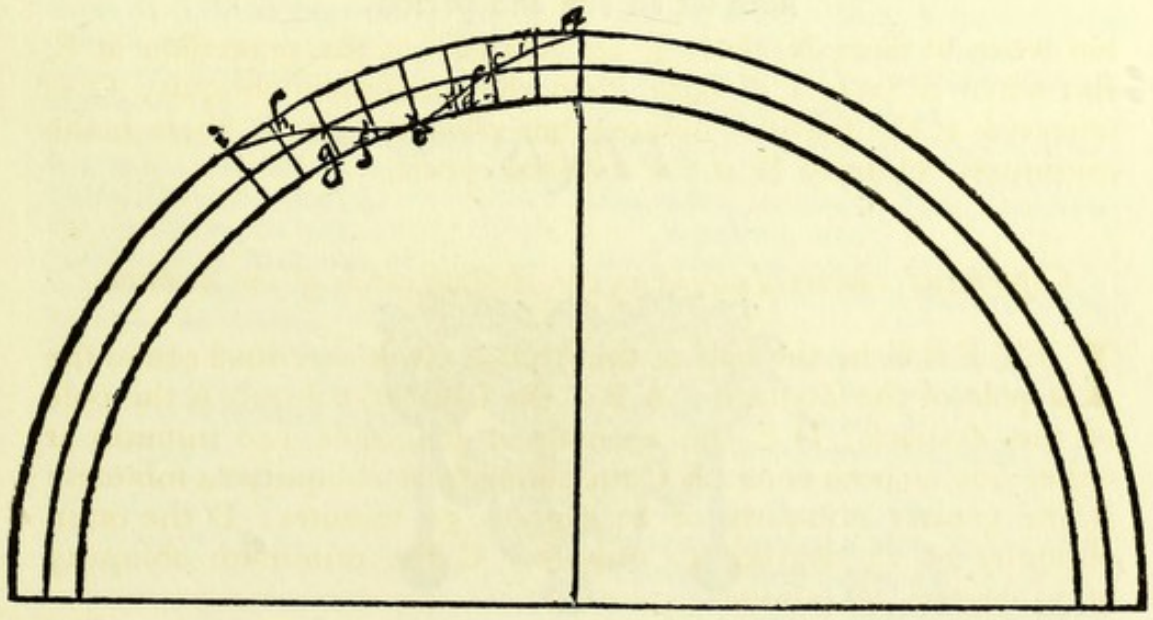
LET F B G be the half of the Arctick circle deſcribed round the pole of the Zodiack: A B C the ſolſtitial colure: A the pole of the Zodiack; D E the anomaly of longitude 140 minutes at either ſide on both ends: B C the anomaly of obliquity 24 minutes: B the greater obliquity of 23 degrees 52 minutes: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

The



The true and natural motion of the axis or pole of the *Earth directed to the Arctick circle of the Zodiack.*

A I is part of the Arctick circle of the Zodiack, in which one period of obliquity is performed; from A to E is the period of the anomaly of the præceſſion of the æquinoxes; A I is the ſhape of the curved line which the pole of the Earth deſcribes by a true motion compounded of the three motions, that is to ſay, of the æquable motion præceſſional, of that of the anomaly of the præceſſions, and that of obliquity.



The

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 A I 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), 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.

FINIS.

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.