

Chapter 2

The Life and Death of a Magnet

*The loadstone and iron present and exhibit to us wonderful
subtile properties.*

—William Gilbert

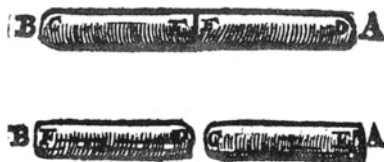
2.1 Introduction

In the first four chapters of Book III of his *De Magnete*, William Gilbert described the laws that govern magnetic bodies. For instance, he noted how a magnetized needle, which is ordinarily oriented along Earth’s magnetic meridian, “quits the earth’s poles” when placed near a small magnetized sphere, or *terrella*, and reorients itself along the meridian of the *terrella*. He also explained how the fragments of a loadstone orient themselves after having been separated, and how iron may acquire “verticity,” the tendency to orient itself between the poles of a nearby loadstone. In the next eight chapters, included below, Gilbert expands on these topics, carefully explaining the motion of iron wires and compass needles placed near, or even inside of, small magnetized spheres. He also explains how magnetism can be born, so to speak, during the industrial process of smelting, and under what circumstances magnetic properties can change and die.

2.2 Reading: Gilbert, *On the Loadstone and Magnetic Bodies and on the Great Magnet the Earth*

Gilbert, W., *On the Loadstone and Magnetic Bodies and on the Great Magnet the Earth: a New Physiology, Demonstrated with Many Arguments and Experiments*, Bernard Quaritch, London, 1893. Book III.

Fig. 2.1 The behavior of a magnetized rod when broken in half.—[K.K.]



2.2.1 Chapter V: Of Magnetizing Stones of Different Shapes

Of a magnetized piece of iron one extremity is north, the other south, and midway is the limit of verticity: such limit, in the globe of the terrella or in a globe of iron, is the equinoctial circle. But if an iron ring be rubbed at one part with a loadstone, then one of the poles is at the point of friction, and the other pole at the opposite side; the magnetic force divides the ring into two parts by a natural line of demarkation, which, though not in form, is in its power and effect equinoctial. But if a straight rod be bent into the form of a ring without welding and union of the ends, and it be touched in the middle with a loadstone, the ends will be both of the same verticity. Take a ring, whole and unbroken, rubbed with a loadstone at one point; then cut it across at the opposite point and stretch it out straight: again both ends will be of the same verticity,—just like an iron rod magnetized in the middle, or a ring not cohering at the joint.

2.2.2 Chapter VI: What Seems to be a Contrary Movement of Magnetic Bodies is the Regular Tendency to Union

In magnetic bodies nature ever tends to union—not merely to confluence and agglomeration, but to agreement, so that the force that causes rotation and bearing toward the poles may not be disordered, as is shown in various ways in the following example. Let CD be an unbroken magnetic body, with C looking toward B , the earth's north, and D toward A , the earth's south (Fig. 2.1). Now cut it in two in the middle, in the equator, and then E will tend to A and F to B . For, as in the whole, so in the divided stone, nature seeks to have these bodies united; hence the end E properly and eagerly comes together again with F , and the two combine, but E is never joined to D nor F to C , for, in that case, C would have to turn, in opposition to nature, to A , the south, or D to B , the north—which were abnormal and incongruous. Separate the halves of the stone and turn D toward C : they come together nicely and combine. For D tends to the south, as before, and C to the north; E and F , which in the mine were connate parts, are now greatly at variance, for they do not come together on account of material affinity, but take movement and tendency from the form. Hence the ends, whether they be conjoined or separate, tend in the same way, in accordance with magnetic law, toward the earth's poles in the first figure of the stone, whether unbroken or divided as in the second figure; and FE of the second figure, when the two parts come together and form one body, is as perfect a



Fig. 2.2 Gilbert explains the proper procedure for joining magnets using the grafting of plants.—[K.K.]

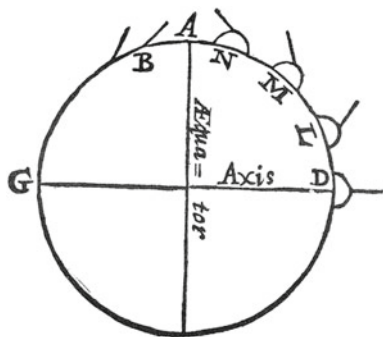
magnetic mass as was *CD* when first produced in the mine; and *FE*, placed on a float, turn to the earth's poles, and conform thereto in the same way as the unbroken stone.

This agreement of the magnetic form is seen in the shapes of plants. Let *AB* be a branch of ozier or other tree that sprouts readily; and let *A* be the upper part of the branch and be the part rootward (Fig. 2.2). Divide the branch at *CD*. Now, the extremity *CD*, if skillfully grafted again on *D*, begins to grow, just as *B* and *A*, when united, become consolidated and germinate. But if *D* be grafted in *A*, or *C* on *B*, they are at variance and grow not at all, but one of them dies because of the preposterous and unsuitable apposition, the vegetative force, which tends in a fixed direction, being now forced into a contrary one.

2.2.3 *Chapter VII: A Determinate Verticity and a Directive Power Make Magnetic Bodies Accord, and not an Attractional or a Repulsive Force, Nor Strong Coition Alone or Unition*

In the equinoctial circle *A* there is no coition of the ends of a piece of iron wire with the terrella; at the poles the coition is very strong. The greater the distance from the equinoctial the stronger is the coition with the terrella itself, and with any part thereof, not with the pole only. But the pieces of iron are not made to stand because of any peculiar attracting force or any strong combined force, but because of the common energy that gives to them direction, conformity, and rotation. For in the region *B* not even the minutest bit of iron that weighs almost nothing can be reared to the perpendicular by the strongest of loadstones, but adheres obliquely (Fig. 2.3). And just as the terrella attracts variously, with unlike force, magnetic bodies, so, too, an iron hump (or protuberance-*nasus*) attached to the stone has a different potency according to the latitude: thus the hump *L*, as being strongly adherent, will carry a greater weight than *M*; and *M* a heavier weight than *N*. But neither does the hump rear to perpendicular a bit of iron except at the poles, as is shown in the figure. The hump *L* will hold and lift from the ground 2 ounces of solid iron, yet it is unable to make a piece of iron wire weighing two grains stand erect; but that would not be

Fig. 2.3 The verticity of an iron needle depends on its location on a magnetized sphere.—[K.K.]



the case if verticity arose from strong attraction, or more properly coition, or from union.

2.2.4 *Chapter VIII: Of Disagreements Between Pieces of Iron on the Same Pole of a Loadstone; How They May Come Together and be Conjoined*

If two pieces of iron wire or two needles above the poles of a terrella adhere, when about to be raised to the perpendicular they repel each other at their upper ends and present a furcate appearance; and if one end be forcibly pushed toward the other, that other retreats and bends back to avoid the association, as shown in the figure (Fig. 2.4a). *A* and *B*, small iron rods, adhere to the pole obliquely because of their nearness to each other: either one alone would stand erect and perpendicular. The reason of the obliquity is that *A* and *B*, having the same verticity, retreat from each other and fly apart. For if *C* be the north pole of a terrella, then the ends *A* and *B* of the rods are also north, while the ends in contact with and held fast by the pole *C* are both south. But let the rods be rather long (say two finger-breadths), and let them be held together by force: then they cohere and stand together like friends, nor can they be separated save by force, for they are held fast to each other magnetically, and are no longer two distinct terminals but one only and one body, like a piece of wire bent double and made to stand erect.

But here we notice another curious fact, *viz.*, that if the rods be rather short, not quite a finger's breadth in length, or as long as a barley-corn, they will not unite on any terms, nor will they stand up together at all, for in short pieces of wire the verticity at the ends farthest from the terrella is stronger and the magnetic strife more intense than in longer pieces. Therefore they do not permit any association, any fellowship. Again, if two light pieces of wire, *A* and *B*, be suspended by a very slender thread of silk filaments not twisted but laid together, and held at the distance of one barley-corn's length from the loadstone (Fig. 2.4b), then the opposite ends, *A* and *E*, situate within the sphere of influence above the pole, go a little apart for the

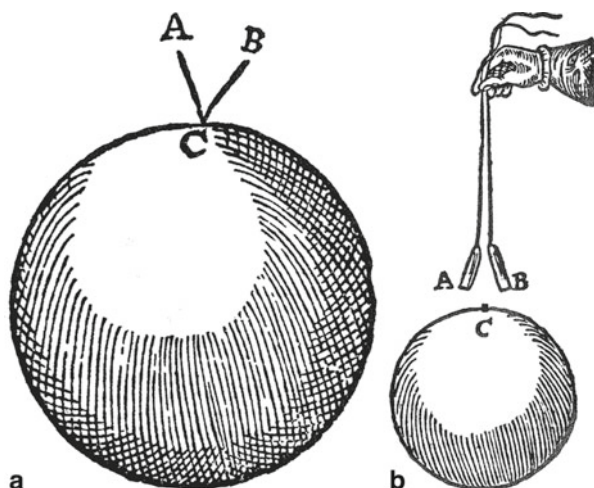


Fig. 2.4 **a** The upper ends of two short iron wires at the pole of a magnetized sphere stand apart; a single wire would stand erect. **b** The ends of two wires suspended by silk thread above the pole of a magnetized sphere are repelled.—[K.K.]

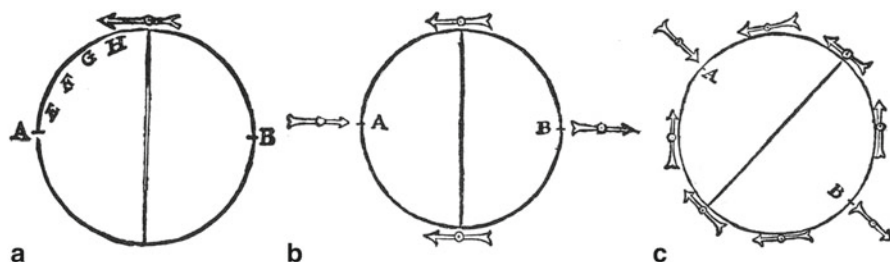


Fig. 2.5 The orientation of a magnetized needle near a spherical loadstone.—[K.K.]

same reason, except when they are very near the pole *C* of the stone: in that position the stone attracts them to the one point.

2.2.5 Chapter IX: Directional Figures Showing the Varieties of Rotation

Having now sufficiently shown, according to magnetic laws and principles, the demonstrable cause of the motion toward determinate points, we have next to show the movements. On a spherical loadstone having the poles *A*, *B*, place a rotating needle whose point has been magnetized by the pole *A* (Fig. 2.5a): that point will be directed steadily toward *A* and attracted by *A*, because, having been magnetized by *A*, it accords truly and combines with *A*; and yet it is said to be opposite because

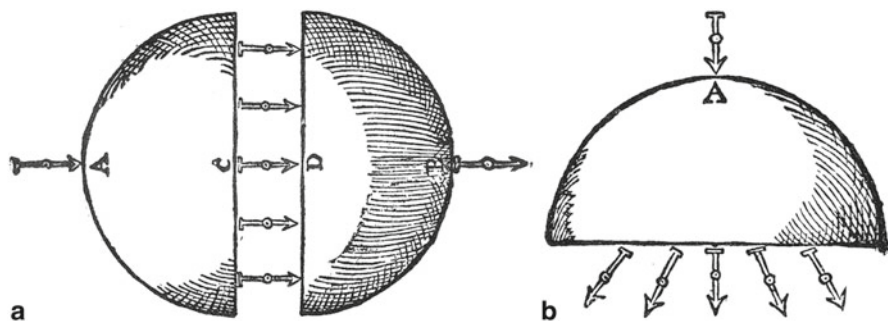


Fig. 2.6 The orientation of magnetized needles placed near a split terrella.—[K.K.]

when the needle is separated from the stone it moves to the opposite part of earth from that toward which the loadstone's pole *A* moves. For if *A* be the north pole of the terrella, the point of the needle is its south end, and its other end, the crotch, points to *B*: thus *B* is the loadstone's south pole, while the crotch of the needle is the needle's north end. So, too, the point is attracted by *EFGH* and by every part of a meridian from the equator to the pole, because of the power of directing; and when the needle is in those places on the meridian the point is directed toward *A*; for it is not the point *A* but the whole loadstone that makes the needle turn, as does the whole earth in the case of magnetic bodies turning to the earth.

The figure following (Fig. 2.5b) shows the magnetic directions in the right sphere of a loadstone and in the right sphere of the earth, also the polar directions to the perpendicular of the poles. All the points of the versorium have been magnetized by pole *A*. All the points are directed toward *A* except the one that is repelled by *B*.

The next figure (Fig. 2.5c) shows horizontal directions above the body of the loadstone. All the points that have been made south by rubbing with the north pole or some point around the north pole *A*, turn to the pole *A* and turn away from the south pole *B*, toward which all the crotches are directed.

I call the direction horizontal because it coincides with the plane of the horizon; for nautical and horological instruments are so constructed that the needle shall be suspended or supported in equilibrium on a sharp point, which prevents the dip of the needle, as we shall explain later. And in this way it best serves man's use, noting and distinguishing all the points of the horizon and all the winds. Otherwise in every oblique sphere (whether terrella or earth) the needle and all magnetized bodies would dip below the horizon, and, at the poles, the directions would be perpendicular, as appears from our account of the dip.

The next figure (Fig. 2.6a) shows a spherical loadstone cut in two at the equator; all the points of the needles have been magnetized by pole *A*. The points are directed in the centre of the earth and between the two halves of the terrella, divided in the plane of the equator as shown in the diagram. The case would be the same if the division were made through the plane of a tropic and the separation and distance of the two parts were as above, with the division and separation of the loadstone

through the plane of the equinoctial. For the points are repelled by *C*, attracted by *D*, and the needles are parallel, the poles or the verticity at both ends controlling them.

The next figure (Fig. 2.6b) shows half of a terrella by itself, and its directions differing from the directions given by the two parts in the preceding figure, which were placed alongside.

All the points have been magnetized by *A*; all the crotches below, except the middle one, tend not in a right line but obliquely, to the loadstone, for the pole is in the middle of the plane that before was the plane of the equinoctial. All points magnetized by parts of the loadstone away from the pole move to the pole (just as though they had been magnetized by the pole itself) and not to the place of friction, wherever that may be in the whole stone at any latitude betwixt pole and equator. And for this reason there are only two differences of regions—they are north and south as well in the terrella as in the great globe of earth; and there is no east, no west place, no regions truly eastern or western, but, with respect to each other, east and west are simply terms signifying toward the east or west part of the heavens. Hence Ptolemy seems in the *Quadripartitum* to err in laying out eastern and western division, to which he improperly annexes the planets; he is followed by the rabble of philosophasters and astrologers.

2.2.6 Chapter X: *Of the Mutation of Verticity and Magnetic Properties, or of the Alteration of the Force Awakened by the Loadstone*

Iron excited by the magnetic influx has a verticity that is pretty strong, yet not so stable but that the opposite parts may be altered by the friction not only of a stronger but of the same loadstone, and may lose all their first verticity and take on the opposite. Procure a piece of iron wire and with the self-same poles of a loadstone rub each end equally; pass the wire through a suitable cork float and put it in the water. Then one end of the wire will look toward a pole of the earth whereto that end of the loadstone does not look. But which end of the wire? It will be just the one that was rubbed last. Now rub with the same pole the other end again, and straightway that end will turn in the opposite direction. Again rub the end that first pointed to the pole of the loadstone, and at once that, having, as it were, obtained its orders (*imperium nactus*), will go in the direction opposite to the one it took last. Thus you will be able to alter again and again the property of the iron, and the extremity of it that is last rubbed is master. And now merely hold for a while the north end of the stone near the north end of the wire that was last rubbed, not bringing the two into contact, but at the distance of one, two, or even three finger-breadths, if the stone be a powerful one; again the iron will change its property and will turn to the opposite direction: so it will too, though rather more feebly, if the loadstone be four finger-breadths away. The same results are had in all these experiments whether you

employ the south or the north part of the stone. Verticity can also be acquired or altered with plates of gold, silver, and glass between the loadstone and the end of the piece of iron or wire, provided the stone be rather powerful, though the plates of metal be touched neither by the stone nor by the iron. And these changes of verticity occur in cast-iron. But what is imparted or excited by one pole of the loadstone is expelled and annulled by the other, which confers new force. Nor is a stronger loadstone needed to make the iron put off the weaker and sluggish force and to put on a new. Neither is the iron “made drunken” (*inebriatur*) by equal forces of loadstone, so that it becomes “undecided and neutral,” as Baptista Porta maintains. But by one same loadstone, and by loadstones endowed with equal power and strength, the force is altered, changed, incited, renewed, driven out. The loadstone itself, however, is not robbed, by friction with another bigger or stronger stone, of its property and verticity, nor is it turned, when on a float, to the opposite direction or to another pole different from that toward which, by its own nature and verticity, it tends. For forces that are innate and long implanted inhere more closely, nor do they easily retire from their ancient seats; and what is the growth of a long period of time is not in an instant reduced to nothing unless that in which it inheres perishes. Nevertheless change comes about in a considerable interval of time, *e.g.*, a year or two, sometimes in a few months—to wit, when a weaker loadstone remains applied, in a way contrary to the order of nature, to a stronger, *i.e.*, with the north pole of one touching the north pole of the other, or the south of one touching the other’s south. Under such conditions, in the lapse of time the weaker force declines.

2.2.7 Chapter XI: Of Friction of Iron with the Mid Parts of a Loadstone Between the Poles, and at the Equinoctial Circle of a Terrella

Take a piece of iron wire not magnetized, three finger-widths long (twill be better if its acquired verticity be rather weak or deformed by some process); touch and rub it with the equator of the terrella exactly on the equinoctial line along its whole tract and length, only one end, or both ends, or the whole of the iron, being brought into contact. The wire thus rubbed, run through a cork and float it in water. It will go wandering about without any acquired verticity, and the verticity it had before will be disordered. But if by chance it should be borne in its wavering toward the poles, it will be feebly held still by the earth’s poles, and finally will be endowed with verticity by the energy of the earth.

2.2.8 *Chapter XII: How Verticity Exists in All Smelted Iron not Excited by the Loadstone*

Hitherto we have declared the natural and innate causes and the powers acquired through the loadstone; but now we are to investigate the causes of the magnetic virtue existing in manufactured iron not magnetized by the loadstone. The loadstone and iron present and exhibit to us wonderful subtile properties. It has already oft been shown that iron not excited by the loadstone turns to north and south; further, that it possesses verticity, *i.e.*, distinct poles proper and peculiar to itself, even as the loadstone or iron rubbed with the loadstone. This seemed to us at first strange and incredible: the metal, iron, is smelted out of the ore in the furnace, flows out of the furnace, and hardens in a great mass; the mass is cut up in great workshops and drawn out into iron bars, and from these again the smith fashions all sorts of necessary implements and objects of iron. Thus the same mass is variously worked and transformed into many shapes. What, then, is it that preserves the verticity, or whence is it derived? First take a mass of iron as produced in the first iron-works. Get a smith to shape a mass weighing 2 or 3 ounces, on the anvil, into an iron bar one palm or 9 in. long. Let the smith stand facing the north, with back to the south, so that as he hammers the red-hot iron it may have a motion of extension northward; and so let him complete the task at one or two heatings of the iron (if needed); but ever while he hammers and lengthens it, have him keep the same point of the iron looking north, and lay the finished bar aside in the same direction. In this way fashion 2, 3, or more, yea 100 or 400 bars: it is plain that all the bars so hammered out toward the north and so laid down while cooling will rotate round their centres and when afloat (being passed through suitable pieces of cork) will move about in water, and, when the end is duly reached, will point north. And as an iron bar takes verticity from the direction in which it lies while being stretched, or hammered, or pulled, so too will iron wire when drawn out toward any point of the horizon between east and south or between south and west, or conversely. Nevertheless, when the iron is directed and stretched rather to a point east or west, it takes almost no verticity, or a very faint verticity. This verticity is acquired chiefly through the lengthening. But when inferior iron ore, in which no magnetic properties are apparent, is put in the fire (its position with reference to the world's poles being noted) and there heated for 8 or 10 h, then cooled away from the fire and in the same position with regard to the poles, it acquires verticity according to its position during heating and cooling (Fig. 2.7).

Let a bar of iron be brought to a white heat in a strong fire, in which it lies meridionally, *i.e.*, along the track of a meridian circle; then take it out of the fire and let it cool and return to the original temperature, lying the while in the same position as before: it will come about that, through the like extremities having been directed toward the same poles of the earth, it will acquire verticity; and that the extremity that looked north when the bar, before the firing, was floated in water by means of a cork, if now the same end during the firing and the cooling looked southward, will point to the south. If perchance the turning to the pole should at any time be weak



Fig. 2.7 An iron smelting shop.—[K.K.]

and uncertain, put the bar in the fire again, take it out when it has reached white heat, cool it perfectly as it lies pointing in the direction of the pole from which you wish it to take verticity, and the verticity will be acquired. Let it be heated again, lying in the contrary direction, and while yet white-hot lay it down till it cools; for, from the position in cooling (the earth's verticity acting on it), verticity is infused into the iron and it turns toward points opposite to the former verticity. So the extremity that before looked north now turns to the south. For these reasons and in these ways does the north pole of the earth give to that extremity of the iron which is turned toward it south verticity; hence, too, that extremity is attracted by the north pole. And here it is to be observed that this happens with iron not only when it cools lying in the plane of the horizon, but also at any inclination thereto, even almost up to perpendicular to the centre of the earth. Thus heated iron more quickly gets energy (strength) and verticity from the earth in the very process of returning to soundness in its renascence, so to speak (wherein it is transformed), than when it simply rests in position. This experiment is best made in winter and in a cold atmosphere, when the metal returns more surely to the natural temperature than in summer and in warm climates.

Let us see also what position alone, without fire and heat, and what mere giving to the iron a direction toward the earth's poles may do. Iron bars that for a long

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